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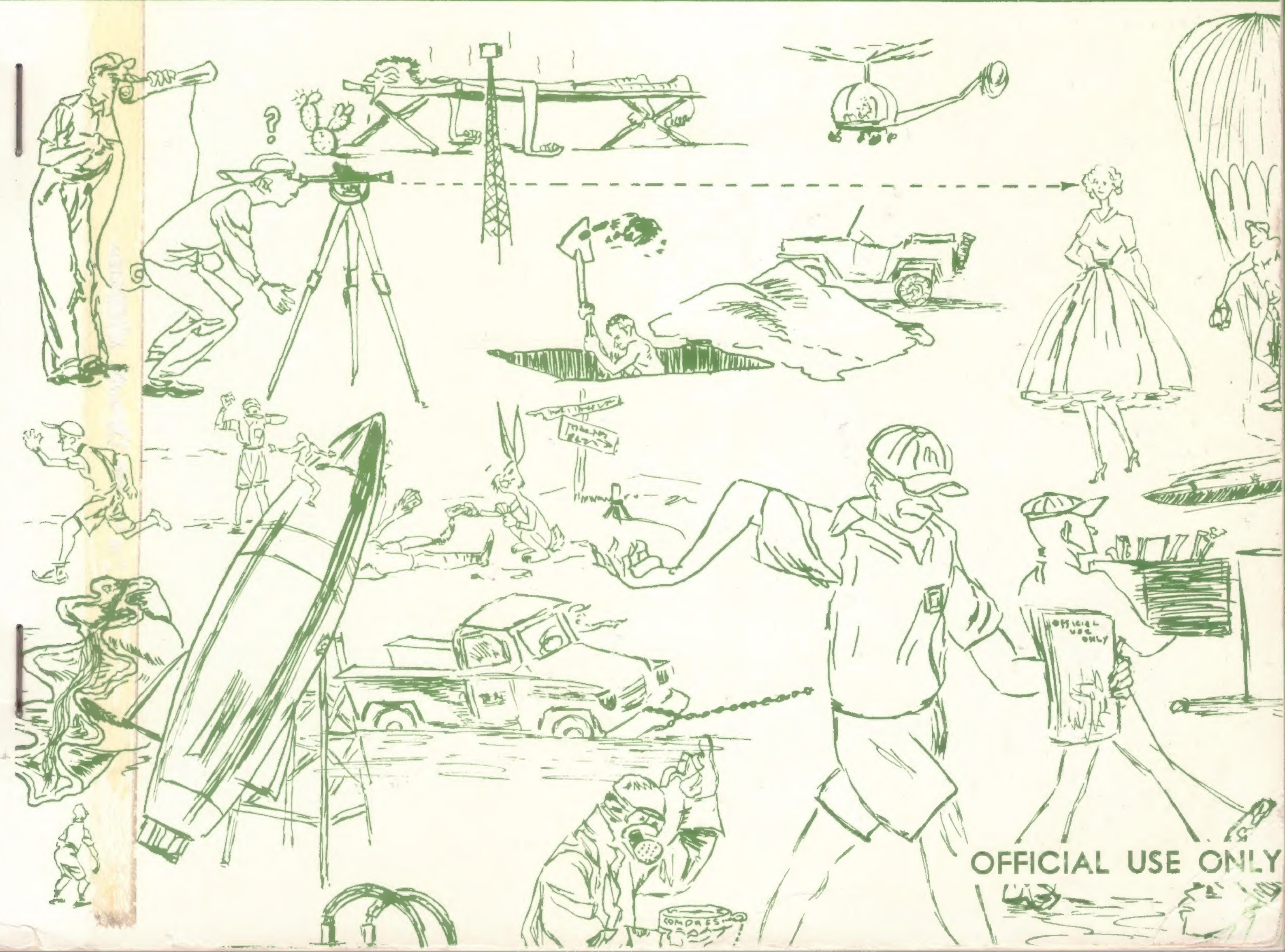
MEASURING MILITARY EFFECTS OF NUCLEAR WEAPONS



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MEASURING MILITARY EFFECTS OF NUCLEAR WEAPONS

A Manual for the Conduct of Full-Scale Field Tests

Compiled
by

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

for

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Chapter 1
THE FIELD EXPERIMENT

You have a project, you have the green light, and you have just been received into that stalwart fraternity who marches resolutely to the blistering sands of Nevada and the soggy atolls of the Marshalls, on alternate years, to measure the effects of nuclear weapons. If this is your first field junket, you'll find conditions very different from the laboratory. If you've been out on field tests before, but never on nuclear field tests, you'll find a number of peculiarities. If you've been out on nuclear field tests before, you can stop here. You are probably only too well aware of those peculiarities.

If you are a "first timer" you will find that the history of nuclear weapons development and testing is a tradition of ingenuity and initiative. From the beginning, Operation Crossroads in 1946, experimenters have been chosen for their competence, and this quality has been sustained throughout the series of field tests.

Whether you are new to weapons effects tests or are an old hand at them, listed here are a few of the characteristics of these tests which, if neglected in the planning of an experiment, can cause loss of weight, prematurely graying hair, insomnia, and nervous tics in an otherwise healthy project leader.

1. Probably the most important single aspect of a weapons effects experiment is that it is a one-shot affair. Everything is planned around that brief moment of detonation, and no amount of second guessing is useful. This also means that there is little opportunity and less desirability for on-the-spot improvisation. Haywire construction can be disastrous.

2. The natural environment of the test site, i.e., climate, terrain, etc., has to be considered in planning the experiment.

3. Constant cooperation keynotes the success of a test series, and this extends from the borrowing of a Ramset gun to the compromise between the ideal station location and the next best. There are a number of unrelated projects on each test shot which means that cooperation and compromise are routine procedure.

4. Lines of supply are long, which leads to higher than normal construction costs and longer delivery times.

5. Distances over which personnel and equipment must operate are large; the capability of equipment mobility is desirable.

6. At times, it is necessary to sacrifice a certain amount of precision and standard laboratory procedure to operate successfully.

7. Morale of working personnel, always an important aspect of a group activity, may take on additional significance in field test work.

In addition to the above-mentioned general considerations, there are some operational "rules of the game" which are peculiar to the field tests of weapons effects.

In nuclear test series there are two types of shots: Atomic Energy Commission (AEC) development shots and Department of Defense (DOD)-AEC military effects shots. The date of firing is established by the weapons laboratories, and for the average experimenter, this means that plans may change every time there is a change in the shot schedule. Although the yields of the development shots are only estimated, DOD contractors often participate on these events. The DOD-AEC military effects shots, which are specifically requested by DOD, usually make use of a device whose yield is well

known. The military effects shots are most heavily instrumented by DOD contractors, although AEC contractors often participate as well.

Because of the interdependence of operations and personnel during a test series, a schedule of test dates is set up and adhered to as closely as is feasible. Although individual shots may be delayed past the scheduled date due to weather and technical difficulties, as far as the weapons effects experimenter is concerned, the shot is detonated "ready or not" on the scheduled day. For that reason, the temptation to crank a possible shot postponement into a work schedule should be avoided. Of course, there are occasions when the shot schedule for one reason or another must be juggled; for example, when it becomes desirable to detonate a device of smaller yield instead of the one regularly scheduled for test. The experiment plan must be flexible enough to meet this exigency. The importance of flexibility is also evident when the decision to postpone a shot is made as late as an hour or two before scheduled detonation time.

A final rule to live by is: It always takes longer to do things in the field than you have estimated, perhaps 2 to 3 times longer.* The chief factors leading to delays are poor weather, construction problems, material procurement difficulties, lack of specialized or skilled personnel, and low personnel morale.

To further hackney a hackneyed phrase, in planning a weapons effects experiment, there is no substitute for experience. If it is at all possible, include in the field party those who have had field experience, preferably on an effects test operation. For a sea operation, it is valuable to include people who have some knowledge of seamanship (see Chapter 4).

Catalogued in this chapter are the considerations that go into a test operation. These considerations are taken up in more detail in individual chapters and are presented here to give a chronological picture of a typical operation.

BEFORE GOING TO THE FIELD

Programs and Program Directors

Customarily, the DOD Test Group (NTS) and Task Unit 3 (EPG) are arranged in the following technical groups.

Program	Description
1	Blast and Shock Studies
2	Nuclear Radiation Studies
3	Structures Studies
4	Biomedical Studies
5	Aircraft Studies
6	Military Equipment Studies
7	Detection Methods
8	Thermal Radiation Studies
9	Technical Photography

For each group there is a program director (sometimes two). Before the operation he is to be found at Field Command, Armed Forces Special Weapons Project (FC/AFSWP, Albuquerque) and during the operation, at the site. The program director reviews the technical, operational, and fiscal feasibility of each project's experiment plan, the requirements listed on monthly status reports submitted by the project, and the pretest, interim, and final weapons tests reports required of each project and the positioning report required of Program 5. In general, the program director is the project's best friend Reference 1). It is to him that project officers go for aid and assistance; he has a sympathetic ear and a strong shoulder. The chief thing for the project officer to keep in mind is that the program director is his father-confessor, trouble-shooter, and general liaison for all project needs.

Operating Procedures and Planning Guides

To aid in the planning and execution of a field experiment, each project can expect to receive the following or similar documents prior to a full-scale test operation.

*Because of the physical distances between base camp and shot areas, working hours at Eniwetok Proving Ground (EPG) number about 10 compared with nearly round-the-clock working time at Nevada Test Site (NTS).

TABLE 1.1 TEST MANUALS AND PLANNING GUIDES

Document	Pacific Operation	Nevada Operation
Task Group 7.1 Administrative Plan (and concept)	x	
Weapons Effects Tests Planning Directive		x
Security and Administration Annex	x	x
AFSWP Manual for Budgeting and Administration of Funds	x	x
Test Manager's Standard Operating Procedure		x
AEC-DOD Classification Guide OC-DOC 38	x	x
AEC-DOD General Classification Guide for Continental Test Operations OC-DOC 52		x
Weapon Effects Tests Standing Operating Procedures Field Command/AFSWP	x	x
AEC-DOD General Classification Guide for Pacific Operations	x	
Nevada Test Site Information Handbook		x
Preparation of Weapon-Effect Reports	x	x
Anatomy of Eniwetok: The Eniwetok Proving Ground	x	
Catalog of AFSWP Test Equipment and Related Items	x	x

The value of studying these publications cannot be over-emphasized. It is especially important that the cognizant person within each agency be made aware of the material which bears upon his particular responsibility so that the experiment gets underway smartly. For example, the material related to personnel security clearances and handling of classified information at the test site should be referred to the group's security officer at the earliest possible date, the shipping instructions for equipment should be put in the hands of the shipping department, and so on. Details of these are available in the "Security and Administration Annex" and/or the "Standard Operating Procedures" and "Operations Plans."

Three other documents, "Status of WT Reports," "Cumulative Subject Guide to Weapons Tests Information," and "Abstracts of Weapons Tests Reports" (References 2, 3, and 4), although not issued automatically to all agencies, are invaluable.

Project Officers and Interagency Cooperation

From experience on several test operations, a project suffers if it has a project officer who is displaced physically from the laboratory which has the technical responsibility for carrying out the project. If a truly administrative project officer is chosen, he should be stationed at the home laboratory during planning stages, and he should have on-site technical assistance from representatives at the home laboratory. It is important that the project officer be involved in planning, performance, and interpretation phases of the test operation.

From one who has been that exalted figure, the project officer, comes some cogent suggestions for his "colleagues of the cloth."

Appoint a deputy. No matter how small the project, the project leader should have an alternate designated to speak for the

leader in his absence.

Leave one good man behind. There should be at least one person at home base who is aware of project's objectives and requirements. This will be the contact man when the project calls home for help.

Set up and promulgate your house rules well in advance. All project people should be filled in on the project officer's planned method of operation in the field. This goes beyond the normal responsibilities of informing people of their duties and assignments, etc., and should include how the project officer intends to handle the overall working schedules, recreation, and rotation home. With some advance warning of the necessary "hurry up and wait" routines in the field, the uninitiated may not be so shocked. Also, a little reflection on problems of working hours may avoid morale problems in the field.

Do not expect everybody to be at peak efficiency in the field. Whether they admit it or not, most people are slowed down by the general working conditions in the field and are not likely to be as creative or productive as in their normal jobs at home.

For purposes of interagency cooperation and coordination, one man from each project should be assigned to do the necessary liaison work between projects. This may bring the liaison man to the field ahead of the main party. This method saves time and energy and makes for smoother relations between projects. For coordination of effort under different DOD test programs, it is best to work through AFSWP Field Command and the appropriate program directors. Often, if two agencies, one of which is not a DOD contractor (one may be an AEC contractor), have a conflict an informal discussion can be arranged by AFSWP to iron out problems of interference.

If possible, clerical personnel should be included in the field party to relieve technical personnel from having to take time away from field work to attend to clerical details. Women are often assigned to these jobs at NTS (and to technical duties as well); EPG, however, is an all-male operation.

Personnel

Some little thought should go into selection of personnel for field expeditions. The jobs to be done call for skilled people, and it is important to have competent help on a field project. In the field there is often no separation of activities between planning and doing. However, whenever possible a scientist's talents for driving nails, splicing cable, and typing event cards should not be used when he might otherwise be solving an equation, computing estimated explosion effects at certain distances, or analyzing records. This means that the project leader must consider carefully the number of jobs to be done, the time allowed for their doing, and on this basis select his field party. This means that the project leader may want to divide the responsibilities among people adept at administration, logistics, and so forth, so that there is an "office" crew and "technical" crew. However, there is a fine balance to be maintained between having sufficient project personnel on hand and having no superfluous people. This is often not easy to achieve because of the hurry up and wait activities that may demand fifteen people one week, four the next, and fifteen again the third week. Sometimes an oversupply of project personnel is unavoidable, and during these times, if it is feasible, some personnel can be sent home for a break in the routine.

"It is important that the project officer be involved in the planning, performance, and interpretation phases of the test operation."

Instrument Recovery and Shipment

When the field phase is over, there is still the job of instrument recovery and shipment (roll-up) back to the home laboratory, see Chapters 10, 14, and 20. A record of all instruments recovered should be kept, noting their condition, position, and any unusual observations; this may aid in data reduction for the final report.

For shipments from the test site, follow the same procedure on marking and crating as outlined in Reference 6. Also, to insure complete and prompt shipment, all equipment must be shipped before the last project personnel leave the test site.

POSTSHOT EXPERIMENTS

At the moment when the fireball invades the sky most experimenters can breathe a sigh of relief. The shot has "gone," and for them the die is cast. For the man involved in after-the-fact measurements, however, this means that his work has just begun.

Two things characterize such postshot experiments. Their stations may be but are not necessarily at relatively long distances from the test site,* and there are numerous stations (from simple to complex). In addition, some activities are carried on long after the operational phase is over. With these characteristics in mind the long-range experimenter is obliged to remember that communications, transportation, and logistics are perhaps of substantially more importance to him than to the on-site, zero-time participant.

Project personnel at outlying stations involved, for example, in water wave studies must be kept informed constantly of burst characteristics and conditions. There has to be a direct undelayed system for transmitting such information. Radioecology teams, poised in the early morning darkness ready to place their stations, have to know directly, early, and as precisely as possible the direction the fallout will take. These teams are coordinated by air-to-ground radio contact by the project leader in a communications aircraft.

Projects concerned with fallout on the ocean and on land often require special transportation and communication systems for the success of their efforts.

Timing can be another significant feature of a postshot experiment. (See Chapter 7 for a discussion of timing signals postshot.)

Placement of phantoms, for example, at a certain radiation level at a certain time (postshot) can be facilitated by the use of helicopters instead of trucks, although the dust kicked up by helicopters is a threat to their airworthiness. Whenever multiple stations have to be established simultaneously, time is critical. Frequent rehearsals will establish the minimum time necessary for the operation.

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*See Chapters 4 and 20 for a discussion of off-site projects.

Chapter 2
THE MEASUREMENT SYSTEM

What was earlier referred to as "the romance of field testing" influences to a large extent the philosophy and character of weapons effects measurement; it is a challenging experience. The newcomer to the field of nuclear weapons effects need not be an expert in nuclear engineering or physics. The basic phenomena are the same whether they occur in the field or elsewhere. It is only the conditions (environment) of their occurrence that set them apart. The continuous challenge to the full-scale nuclear test experimenter is to isolate his instrumentation from the effects not being measured and to pluck out of the vast interplay of physical phenomena only that one phenomenon which he wishes to measure. It is axiomatic that the proper isolation of instrumentation must be preceded by an expanded viewpoint toward this interplay of explosion phenomena.

This chapter and the three chapters following attempt to give the experimenter a feeling for the types of technical problems that will confront him and his field measurements. As often as possible the statement of the problem is followed by its solution, derived from experience; however, not all the problems are solved--and even if they were, enterprising people would soon invent new ones.

PHILOSOPHY

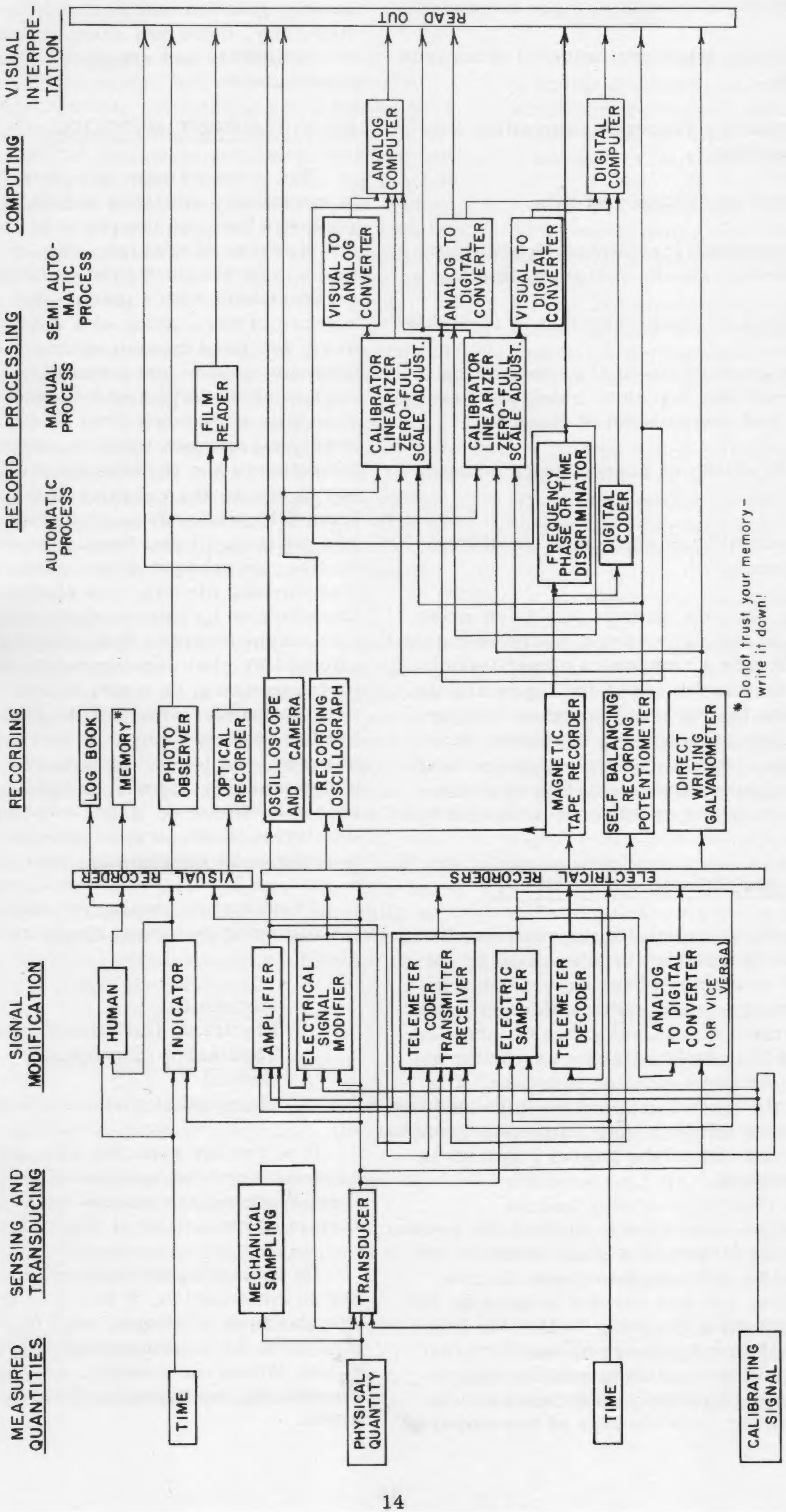
The philosophy of effects instrumentation can probably be summed up by saying that a systems approach is required, with an aim toward establishment of a standard capability for a particular type of measurement. This has come about because of the increased understanding of the forces with which the experimenter is dealing and because more extensive and increasingly accurate measurements are needed. Trial and error techniques of the "old days" are giving way to more sophisticated systems, and there is greater concern over quality than there is over quantity of measurement.

This is not to say that there is no room for imagination and invention. In the design of weapons effects instrumentation, there has always been the ingenious--for example, the British and their toothpaste tube blast gages, or the use of a parabolic mirror placed at a safe distance from blast effects which allows samples to be exposed to the same intense thermal radiation that occurs at ground ranges where blast would destroy the samples, or the use of semiconductors as neutron detectors because their reaction to neutrons is permanent and does not require quick counting (and therefore no early entry), or the use of a tape loop in rocket telemetry so that if the signal is masked by ionization at zero time it is repeated often enough to insure data recovery. Instrumentation is a dynamic field with continuous development of new designs.

One of the chief regrets expressed by the weapons effects experimenter is that he never has sufficient time to carry out instrumentation development as thoroughly as he could wish. A part of this development process is the exchange of ideas among experimenters, and there is seldom enough time for this, either. Since there is no place for an isolationist attitude in weapons effects experiments, the interchange of ideas and techniques should be actively encouraged.

Some of the factors that should go into the consideration of an instrumentation system for field use are the following:*

*It will be noted that conspicuously absent from this discussion is money. Somehow, when costs are mentioned, the romance quickly fades from the weapons effects field. We leave the matter of costs to the project officer, his budget, and his conscience.



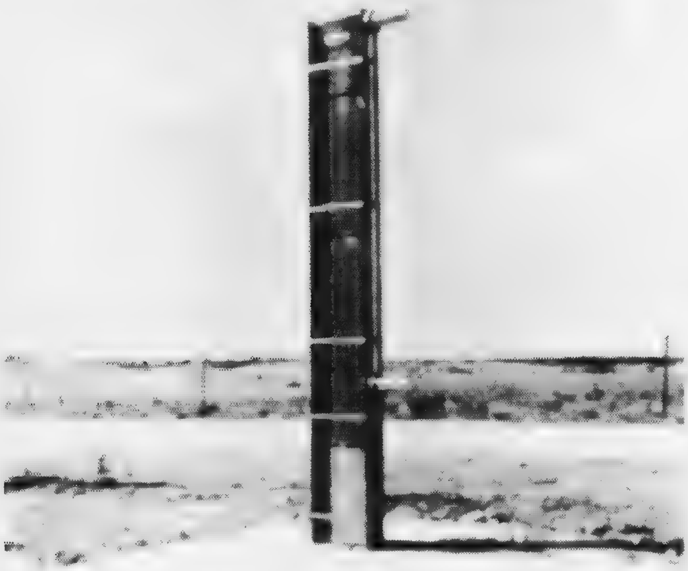
2.1 Instrumentation flow chart

BRL dynamic pressure gage adapted to AFSWP mount

Pressure gage mounted on structure

Ground baffle (tape over sensing port is removed preshot)

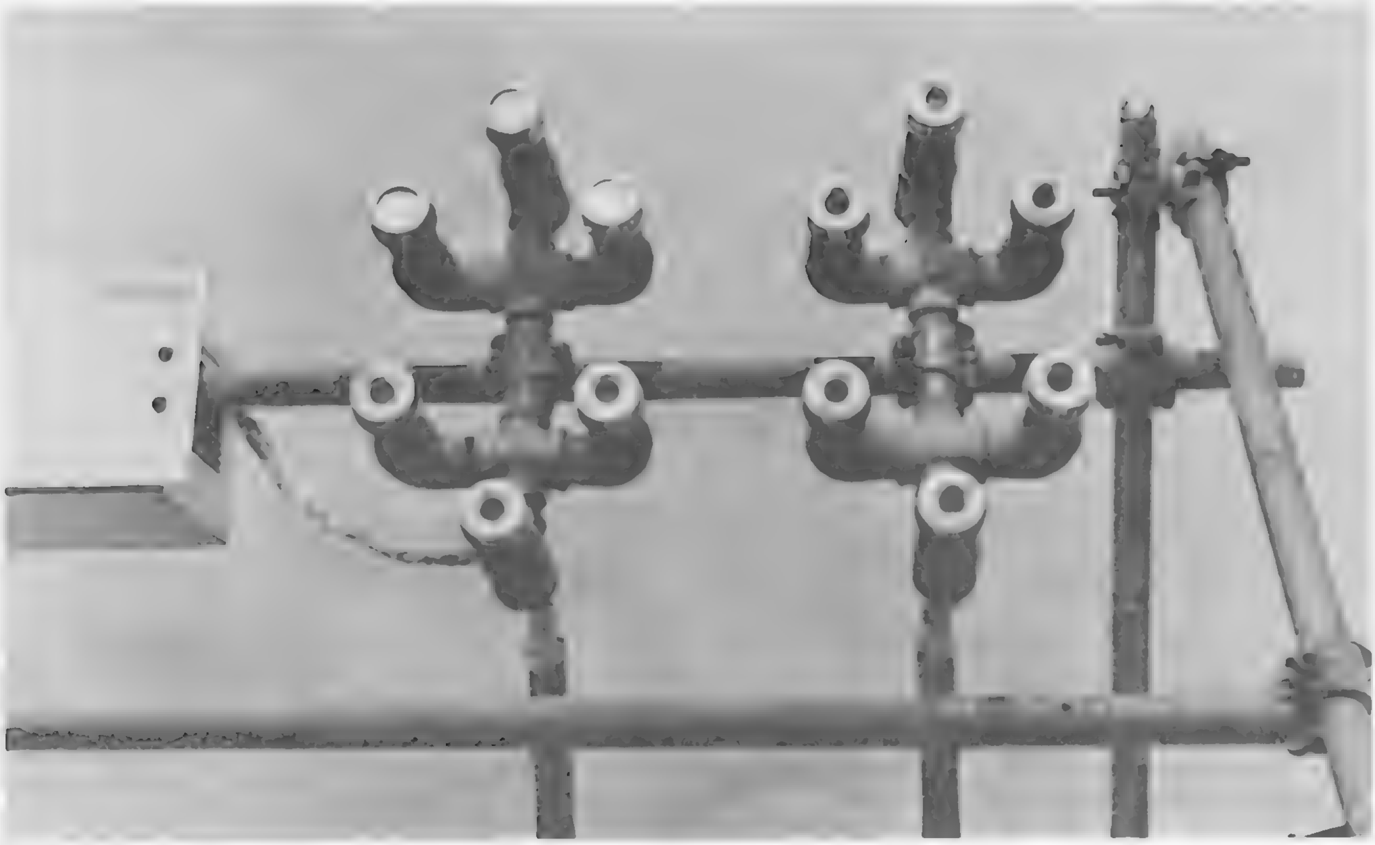
British drag gage, close-up



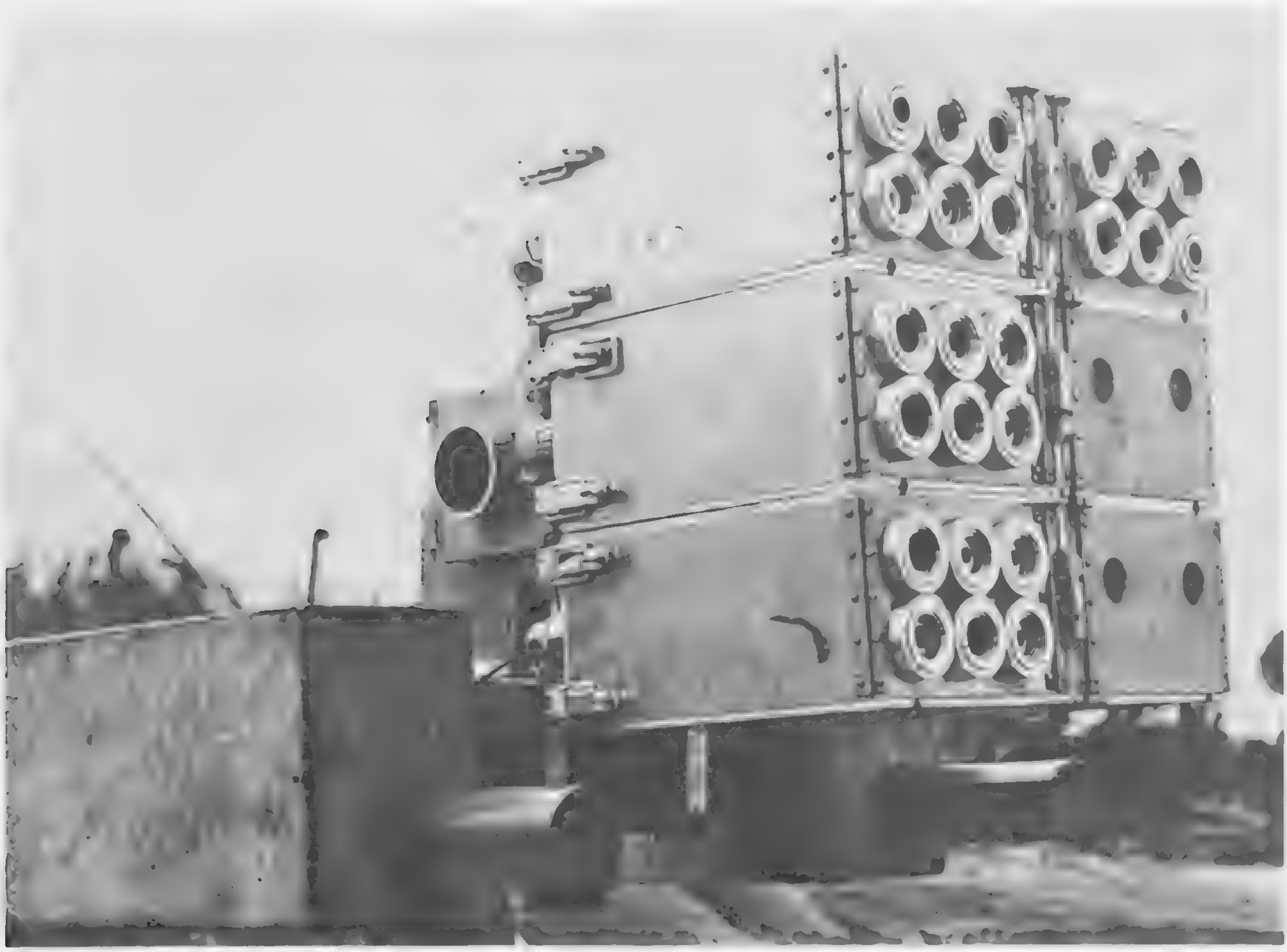
British drag gage mounted on tower

SRI total pressure gage installed

2.3 Examples of pressure gages



Open-type detector housing, for use on A-frame mounting



Closed-type detector housing, for use in high overpressure and thermal radiation areas

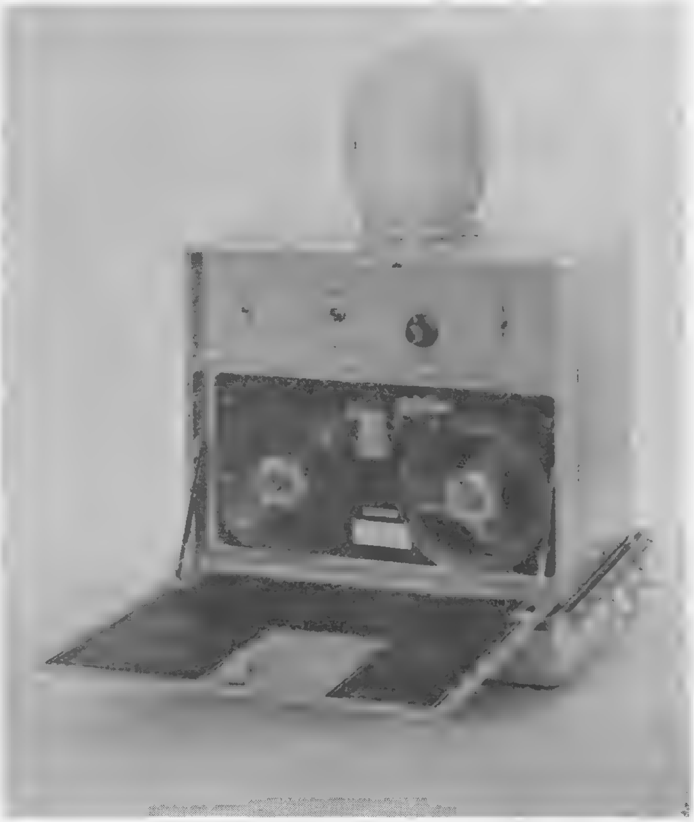
2.4 Examples of thermal radiation measuring devices

Fallout sampler array on YAG

Air sampler installed on-site

ASP (atmospheric sounding projectile)

Preparing greased trays



Gamma-intensity-time recorder

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91. Dust Density vs Time and Distance in the Shock Wave, CRL/ACC, Operation Teapot, WT-1113, 1957 (CRD)

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96. Physical Characteristics of Thermal Radiation from an Atom Bomb Detonation, NRDL, Operation Upshot-Knothole, WT-773

97. Evaluation of Eye Protection Afforded by an Electromechanical Shutter, WADC, Operation Plumbbob, ITR-1429, 1957 (C)

98. Evaluation of Self-Recording Thermal Indicators, CRL, Operation Redwing, ITR-1340, 1956 (SRD)

99. Distribution and Density of Missiles from Nuclear Explosions, LF, Operation Teapot, WT-1168, 1955 (U)

100. Missiles Secondary to Nuclear Blast, LF, Operation Plumbbob, ITR-1468, 1957 (C)

101. Title Classified, NOL, Operation Castle, WT-922, 1955 (SRD)

102. Minefield Clearance by Nuclear Weapons, ERDL, Operation Plumbbob, ITR-1435, 1957 (C)

103. Radiation Energy Absorbed by Human Phantoms in a Fission Fallout Field, NMRI, Operation Teapot, WT-1120, 1955 (C)

104. Evaluation of Standard Navy Dosimeters D1-60/PD & TM-107/PD in Residual Radiation Fields Aboard Ships, BuShips, Operation Redwing, WT-1350, 1957 (C)

105. Attenuation of High Frequency and Ultra High Frequency by Ionization Resulting from Nuclear Explosions, NRL, Operation Redwing, ITR-1346, 1956 (SRD)

106. Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation, DOFL, Operation Plumbbob, ITR-1436, 1956 (SRD)

107. In-flight Structural Response of an FJ-4 Aircraft to a Nuclear Detonation, BuAer, Operation Plumbbob, ITR-1433, 1957 (CFRD)

108. Cloud Photography, AFSWP, Operation Redwing, ITR-1343, 1956 (SRD)

109. Rosenski, J., Efficiency of Scavenging Devices Used in Determining Fallout, ARF, AECU-3486, Jan. 25, 1957 (U)

110. Lusser, R., Unreliability of Electronics, Cause and Cure, Research and Development Division, Ordnance Missile Laboratories, Redstone Arsenal, Nov. 1957 (U)

111. Initial Gamma Radiation Intensity and Neutron-Induced Gamma Radiation of NTS Soil, SCEL, Operation Plumbbob, ITR-1414, 1957 (CFRD)

112. Evaluation of Earth Covered Prefabricated Ammunition Storage Magazines as Personnel Shelters, BuDocks, Operation Plumbbob, ITR-1422, 1957 (CFRD)

113. Instrumentation of Structures for Airblast and Ground Shock Effects, BRL, Operation Plumbbob, ITR-1426, 1957 (CFRD)

Supplement 3A
UNDERGROUND OPERATIONS

Area 12 of Nevada Test Site (Fig. 3A.1) was used for the first time on Operation Plumbbob for Rainier shot, an underground detonation (900 feet below the surface) (References 6 and 7). Area 12 is a mesa to the northwest of Yucca Flat (Fig. 3A.2) rising about 3,000 feet above the valley floor (or ~7,500 feet above sea level), with the last 1,500 feet an abrupt rise. The mesa is chiefly made up of volcanic tuff. The face of the mesa is rocky; the top is uneven, rocky, and has a ground cover of underbrush and pinon and juniper trees, with some of the latter reaching heights of 25 feet.

According to USGS data, * the mesa is made up of three general types of material. Of the total section, about 70% can be classified as typical tuff (volcanic ash), about 15% poorly consolidated tuff, and about 15% welded tuff (rhyolite). In the mesa area above the underground test site, typical tuff is absent and welded tuff forms the top 200- to 300-foot layer of the formation.

The three general types of tuff have the following characteristics (Table 3A.1).

As a site of weapons effects tests, Area 12 presents an environment substantially different from that of Yucca and Frenchman Flats. Part of the preshot activity is carried out on the top and side of the mesa, the remainder in long (~2000 to 6000 feet) corridors tunneled horizontally into the rock at the face of the mesa.

Working in a rock tunnel may present some of the same problems that are found in the Pacific--namely, high humidity and ground water (Fig. 3A.3), although most of the free water is brought in in the tunneling operations. ERDL, for example, found that some of the holes dug in the tunnel floor filled in before gages could be installed and had to be re-dug. Also, it found that by mixing somecement with the water in the bottom of the hole further filling was inhibited. It also found that tape used to seal cable and connector joints had a tendency to come "unstuck" in the dampness of a tunnel. Melted tar was used by Sandia Corporation to hold tape in place. Gage cables should be waterproofed even if the gage itself if placed in a waterproof canister.

TABLE 3A.1 AREA 12 TUFF CHARACTERISTICS

Characteristic	Typical Tuff	Poor Tuff (sand)	Welded Tuff (rhyolite)
Density (gms/cc)	1.57 ± 0.16	1.6 ± 0.2	1.9 ± 0.2
Av. available porosity (% by volume)	30	32	15
Av. total porosity (% by volume, psi)	45	40	35
Compressive strength (approx.)	8600	2000 (est)	high
Tensile strength (psi)	1000 (est)	very small	1/9 compressive
Water content	Corresponds approximately to available porosity: i.e., the tuff which is sufficiently away from free surfaces is nearly or completely saturated with water.		

In general, it is not wise to use test structures as instrument shelters. The shock effects can be disastrous on equipment and records.

Power generators have operated satisfactorily through a pressure of 9 psi. They were located underground to shield them from dynamic pressures, with only the exhaust pipe and gasoline tank exposed on the surface.

Cable breakage due to airblast and/or ground shock is a problem. Most cable breaks have occurred near where the cable enters the tower-mount structure, for it is here that the cable is necessarily most vulnerable to shock effects. Some precautions are: (1) allow plenty of slack in the cable run, particularly near the mount; (2) when splicing cable, tie a knot near the splice to take strain off the splice; (3) tamp earth cover over cable near the mount to prevent scouring action of the shock wave from tearing cable. On shipboard gages can be shock mounted by fastening them to a steel table which is fastened to ship by shock mounts made up of steel pipe.

From the familiar concepts of electrical characteristics certain design precepts suggest themselves in the isolation of functional parts of electronic equipment from the forces of shock and vibration (Reference 15). For instance, make sure that no element of the assembly is excited at the frequency of its resonant mode, or modify the element so that natural modes are achieved which are outside frequency ranges of suspected vibration sources. Inertial force alone, as measured by the g-level of shock and vibration, is not a true indication of the damaging properties of the excitation. Instead, the differentials of motion which are developed across the body are the real cause of structural failures and these failures occur when a body is forced at its resonant frequency. Reliable operation of an electronic assembly may be assured by adjustments which provide attenuation of vibration at the resonant frequencies of its constituent parts in the direction of transmission of mechanical energy.

Ground shock effects upon buried instrument shelters must be considered; however, generally the deleterious effects due to excessive nuclear radiation inside the shelter will usually dictate its range location; and, at this range the ground shock problem can be handled using conventional shock-mount techniques. Warning: Shock mounting should be either thoroughly designed or eliminated completely; half-way measures are not successful. Most electromechanical systems will tolerate rigid mounting to shelters under most typical conditions. Experience at Nevada Test Site shows that a typical concrete instrument shelter, buried and with 1 to 5 feet of earth cover, will suffer a peak acceleration (in g units) of 1/8 to 1/4 the peak overpressure (in psi) recorded at the ground surface over the shelter. This ratio applies in regions of moderate overpressure (less than 15 psi) where the pressure-time waveform is classic; in precursor regions, the ratio may be 1/10 or less.

In Nevada, the very dry and porous soil of the test areas is characterized by high attenuation of the transmission of ground phenomena (Reference 16). For rules of thumb in predicting free field ground motion at a particular station at NTS, a useful expression for acceleration (from which velocity and displacement may be derived) is

$$\text{Acceleration (g units)} = KP,$$

where

P = overpressure, psi

K = proportionality factor between acceleration and overpressure

At NTS, at 5-foot depth, $K = 0.3 - 0.6$.

This same expression may be used for EPG; at the surface (above the water table), $K = 0.5$ to $1/5$; and at 10-foot depth (below the water table), $K = 0.05$ to 0.15 (Reference 17).

Some agencies shock mount their oscillographs in bunkers (shelters) with a rubber pad to withstand approximately 1/2-inch dynamic displacement. Radial and vertical motion is the most troublesome, although there is also a tangential factor.

Another way to shock mount recorders in shelters is with spring mountings. Sandia brings to the field its recording unit in a "package" containing carrier, recorder, oscillators, etc., and installs them on large springs from the ceiling of the shelter. This mounting is satisfactory, even for close-in measurements.

Lockfoam (Nopco Chemical Co., N. J.) is an excellent shock isolator. It can be mixed to different densities, has individual, uncon-

nected cells, and is waterproof. In applying it, be sure to give it expansion room.

Pop-up field radiation survey meters used on Plumbbob, although protected from direct blast and thermal effects by being placed underground, appeared to be affected considerably by ground shock; and in future similar applications would be shock mounted.

Some agencies believe that commercial equipment which is inherently less rugged than military versions withstands ground motion better than the comparatively rigid military equipment.

Finally, the occurrence of airblast-induced water waves at EPG has been the concern of some experimenters in the past. At present, SIO is revising its scaling law for water waves in the lagoon (Reference 18). The result will, it is hoped, give answers within a factor of 2. In the main, the concern is the protection of installations which must be subjected to the blast-induced waves from previous shots; sometimes the water wave effects from other (larger) shots are more severe than similar effects from the shot for which the equipment is installed.

THERMAL RADIATION

The thermal radiation from a nuclear explosion, in addition to its importance as a primary parameter, is used a great deal as a triggering mechanism for other instrumentation, e.g., blue-box and FIDO (see Chapter 7). However, some precautions are necessary to minimize the undesirable aspects of thermal disturbances (Reference 7).

A rule-of-thumb for estimating thermal energy, neglecting atmospheric attenuation, is 1 calorie/cm^2/kt at one mile. The energy is then proportional to yield and inversely proportional to the square of the slant range.

A useful material for thermal shielding is aluminum; it can be obtained in the form of foil and tape. Thermal shielding is necessary for such things as multi-conductor cables, dosimeters, thin glass, plastics, and mechanisms incorporating temperature-sensitive fluids or greases. (Heavy glass has held up at high pressure and thermal levels when it has been used as a blast shield in thermal measurements.) In regions receiving in excess of 15 calories/cm^2 radiant exposure, diaphragm-type strain gage transducers must be shielded.

If you are using aluminum foil close in to protect a painted surface, which you intend to use as a station on recovery, the blast wave may remove the foil before the thermal phase is over and your painted surface will be burned off. In fact, close in, the thermal phase for all considerations, continues long past the blast phase.

Another satisfactory shield is the use of a window shade asbestos curtain.

If you have placed numbered samples in the field, be sure to turn the numbered side away from the bomb light; also black numbers on flammable material will burn through.

White paint is also satisfactory as a thermal shield, especially on water borne gear that may be damaged by wind and waves prior to shot time.

Beware of canvas tarp ignition and fire, if you wish to use it to cover a station; usually the blast wave "blows out" small fires, but a smoldering tarp has been known to cause trouble. If you choose to use sandbags for cover close in, the bags should be covered with a cement slurry to prevent fire.

For triggering devices which make use of the thermal for their operation, it may be desirable to separate the sensing element from the control circuit (Example: separate photocell from the blue-box relays); in this way, it is possible to protect the control unit more effectively from deleterious environmental effects.

ELECTROMAGNETIC (EM) PULSE

In the field of weapons effects testing, if anything approaches the mystic realm, it is the effect due to the transient electromagnetic pulse (sometimes called the induction signal) which occurs a few microseconds after zero time. This pulse has been harassing investigators almost since the beginning (Crossroads) and, sad to say, not much progress has been made in licking the problem although recently greater effort than before has gone into investigating this phenomenon (References 19, 20). The signal, which is confined to a frequency range of a few kc, affects most severely the electrical and electronic components used in instrumentation. Most of the lost data can be traced to transducer inductance coils, transformers, or recording galvanometer coils being short-circuited to ground at an early time (References 21, 22, and 23).

Characteristics

In general, the magnetic component of the EM signal has its largest value in the azimuthal "transverse" direction, as if the field emanated from a vertical electric dipole. Fairly strong components exist in the radial and vertical direction that are almost an order of magnitude weaker and possibly have a different origin. The signal drops off with distance, at a rate of at least $1/r^2$ or possibly as high as $1/r^3$. The fields are reduced to less than 1/10 magnitude of peak value within 100 msec, but weak signals may last for several milliseconds.

For projects measuring blast and shock, the most effective protective measure is to "float" or ground the system before zero time, and then have the blue-box (thermal pulse) signal close a relay which makes the system operative--after the electromagnetic transient has dissipated and before the blast wave has arrived. Still another method which has been used successfully is to connect the transducer case (local ground) to the cable shield (system ground) through neon tubes; also the transducer drive and output leads are coupled to local ground through neons.

For most thermal and prompt nuclear radiation measurements such a scheme would be unacceptable because many of the interesting features of the measurement occur in the first few milliseconds. For these Faraday and/or magnetic (iron or steel) shields have been used to protect instrumentation in underground shelters from the electromagnetic signal (see, for example, Reference 24).

In general, it appears wise to avoid electrical loops wherever possible; most projects ground their instrument cables at the recorder (or transducer) end only, which apparently minimizes the transient effect. Deeper cable trenching has been tried with questionable results. Cable lengths up to 12,000 feet have been used successfully. Although transient trouble has been experienced with conventional wire strain gages, recent flashover techniques have proven successful (Reference 25).

Piezoelectric gages, commonly used for small charge explosions, have been found unsatisfactory for measurements on nuclear explosions (except when used underwater for air or underwater bursts) owing mainly to excessive sensitivity to the transient EM signal.

Central Station and Gage Protection

From the standpoint of the blast and shock effects experimenter, the electromagnetic disturbance at zero time masks no data of importance directly. It is short in duration (not over 5 to 10 msec), whereas most effects of interest begin after 30 to 60 msec from zero time. However, it is prone to damage or paralyze equipment, causing serious loss of data.

Two areas of damage may be considered: (1) central station equipment, and (2) transducer and associated equipment. In general, the central station equipment is at a larger ground range than the transducer, with cables up to several thousand feet long running approximately radially between the two. The signal is also observed, but not so strongly, on cables extending outward from the central station.

Central station damage may take several forms, dependent on the type of equipment. It may consist of burned-out galvanometers or input transformers. It may only consist of overloading or overheating of non-linear elements (ring modulators, etc.), which results in zero shifts or changes in sensitivity without complete loss of data but with serious effects on accuracy. In any case, the effect appears to be due to a large transient flow of current between cable conductors and ground, not usually a flow between balanced conductors. When long cables are used, and no protective measures taken, the loss of data due to central station damage has on occasions been severe (20 to 60% of total).

Transducer damage is a different problem. All cases appear to show evidence of being caused by flashover to (local) ground, either within the transducer element, or at some other point which may cause unbalanced currents to flow and damage the transducer element. There is no evidence of damage due to currents induced in balanced lines.

Central station protection consists of simply grounding the signal lead during zero time. Most channels use a "half-bridge" circuit and a three-wire cable. Two of these wires are connected to a carrier oscillator output transformer whose center tap is grounded. For complete protection, each outer terminal of this transformer is connected to ground through a 2-mfd condenser, al-

though the necessity of these condensers is not proven. The third, or signal lead, is permanently connected to the signal input circuit, but is shunted to ground through a contact of a multi-contact relay. (Several 24-pole normally-open relays are required for large installation.) The relays are actuated a few seconds before zero time. A blue-box signal (two boxes are used for safety) de-energizes the relays through a secondary relay which provides a few milliseconds of delay. Thus the disturbing currents are shunted to ground during the crucial period, but the circuits are restored to normal well before the arrival of any signals pertinent to blast and shock phenomena.

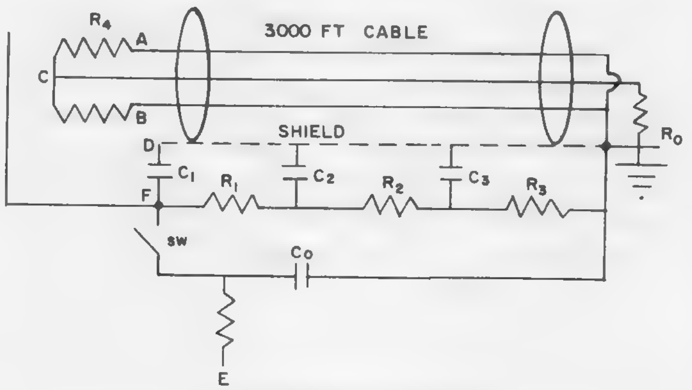
It must be realized that any system such as this introduces the hazard of gross loss of data in case of malfunction. Extreme care must be used in proving its reliability, and it should only be used where probability of damage by the electromagnetic signal is high.

Gage damage has not been significant with balanced-reluctance gages such as the Wiancko or similar devices. The most serious trouble has been permanent grounding of one circuit by the flashover, causing disturbances on other traces. None of these damaged gages was among those nearest ground zero.

When resistance-wire strain gages were used, the record is much poorer, and reports by all agencies show an important proportion of loss up to 100%.

Gages using inductive elements generally flash over at about 1,500 volts, usually at the glass feed-through insulators in the gage case. Paper-base SR-4 strain gages mounted on metal flash over at about 500 volts, through the paper-base, with accompanying destruction of the gage. It was found, however, that the bakelite-based gages, types AB-3 and similar, flash over at 1,500 to 2,500 volts, and then only at the edge where the lead wires protrude, without destroying the gage. If the lead wires are pulled up so that they extend vertically well inside the edge and are surrounded by a spot of insulating cement, they will withstand 5,000 volts, and final failure is at 7,000 to 10,000 volts. This, at first sight, appears to promise satisfactory ruggedness, but such a conclusion ignores the effects of unbalanced currents resulting from flashover at a terminal. The windings of a variable-reluctance transducer will survive a short current pulse of several watt-seconds, while a strain gage winding is destroyed by a short pulse of 0.1 to 0.2 watt-seconds, even though it will dissipate several watts continuously. The damage due to flashover at a terminal or elsewhere can be much greater, therefore, for a strain gage. There is evidence that such a flashover occurs at zero time somewhere in practically every gage circuit on shots like Teapot 12.

To devise further protective means, a synthetic circuit using lumped constants was set up, as shown in Fig. 5.2. In this drawing,



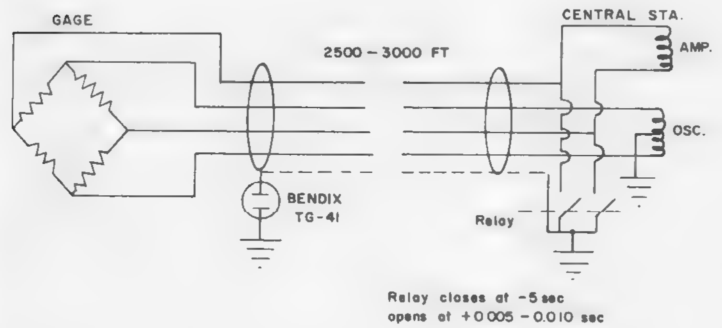
5.2 Synthetic circuit

C_1, C_2, and C_3 are 0.5 mfd, approximately the normal capacitance from shield to ground in a buried cable. R_1, R_2, and R_3, are proportioned to represent the impedance of the earth over a 3,000-foot span. R_4 and R_5 are a 120-ohm half-bridge (the results would be similar with a full bridge and four-wire cable), and R_0 represents the input load of the terminal equipment. C_0 is much larger than C_1, etc., and is charged by E through a resistor. Point F represents the local earth (near the gage). When switch SW is closed, F momentarily jumps to a potential above that of the station earth and decays as C_0 is discharged through R_1, etc. Points A, B, C, and D all rise to the same peak voltage as F but decay faster, since the shield has a lower impedance than the earth. As this voltage decays, then, the potential DF rises to a value smaller than E, but still large. It is important to note that the potentials of A, B, and C follow that of D almost implicity. At no time can any voltage of importance between these points be found, unless they are connected to points D or F separately. The potentials AF, BF, and CF are the ones of interest. When point D is directly connected to point F, AB and C develop no potential to F. This is, however, intolerable for normal field use due to noises from circulating currents.

When a spark gap is placed between D and F, the potential DF (and AF, BF, and CF) is

limited to the breakdown potential of the gap. For input voltages up to 10,000 volts, an automotive spark plug set for an 800-volt DC breakdown was found to work reasonably well, except that its ionization time was long. This caused the potential to rise to a high peak before breakdown when the voltage rise was fast, endangering the gage before the protection became effective.

Among others, Bendix Aviation Corp., Red Bank Div., offers a series of enclosed spark gaps, among which their type TG-41 has a breakdown voltage of 750 volts, a very fast ionization time, and high current-carrying capacity. These devices were used in the circuit of Fig. 5.3; all strain gage channels of Project 1.7 (Operation Plumbbob) gave usable records and no electromagnetic signal effects were observed.



5.3 Circuit, incorporating Bendix spark gaps

NUCLEAR RADIATION

Undoubtedly the biggest "headache" connected with nuclear radiation measurements is the competition between the various radiative components, e.g., measurements of gamma intensities versus time or versus distance must be made in the presence of fast and slow neutrons and beta particles--so the experimenter must either attempt to protect his instrument from the unwanted radiation or determine the instrument sensitivity to the unwanted component and try to correct his data accordingly. Since the aforementioned difficulty is not peculiar to effects testing (those working with nuclear reactors and radiation damage to materials live with it daily), it will be treated only briefly in this manual. Suffice is to say that neutrons are the most troublesome of the unwanted components--they are difficult to shield against and their effect on calibrated films is energy dependent. However, this does not mean that other radiations are not troublesome. In this section are offered for the project planner rules-of-thumb for estimating radiation severity and therefore its effect on his equipment. A good beginning is Fig. 5.4, a nomograph for calculating exposure from initial radiation and Fig. 5.5 a similar nomograph for calculating exposure to residual radiation. Figure 5.6 is a plot for estimating downwind arrival of fallout. (For fallout calculations, see also Reference 26).

Effects of Radiation on Materials

Radiation intensity is inversely proportional to the square of the distance from the source. Each type of radiation, however, affects materials differently. Slow neutrons are captured by atoms in actuation reactions. This induced artificial radioactivity will generally produce secondary gamma rays, as with cadmium. Boron absorbs slow neutrons and emits alpha particles. Of the two, alpha particles are the more desirable since they are easily stopped. The amount of artificial radioactivity induced by slow neutrons is a function of the cross section for capture possessed by the material. Some metals, notably cadmium, cobalt, and manganese have very large cross-sections for slow neutrons (Table 5.2).

Fast neutrons do not have the large cross section for capture possessed by slow neutrons, but they have a large kinetic energy. Fast neutrons damage by elastic collision with atoms in a crystal structure or chemical compound.

Except for ionization and reactions with electrons, gamma rays are not particularly damaging to electronic equipment until quantities of about 10^{18} gamma rays/cm^2 are reached. Ionization of cable insulation has caused intermittant shorting of gage cables laid both on the surface and in trenches.

5.4. ESTIMATE OF EXPOSURE FROM INITIAL RADIATION

Directions

A. Air and Surface Bursts

1. Find distance from ground zero on axis A (titled Distance-Air and Surface). Note that for sea level bursts, distances are marked off along left side of axis, whereas for bursts at 4500 feet, distances are marked off along right side of axis.

2. Find expected yield on axis B (titled Yield). Again note that for sea level, yields are marked off along left hand side of axis and for 4500 feet, yields are marked off along right hand side of axis.

3. A line drawn between chosen points on A and B will intersect C at a point representing the unshielded dose to be expected.

4. The radiation attenuation provided by various thicknesses of concrete, soil, or lead are found on axis D (titled Attenuation by Shielding).

5. A line drawn between chosen points on axes C and D will intersect axis E at a point representing the shielded dose to be expected.

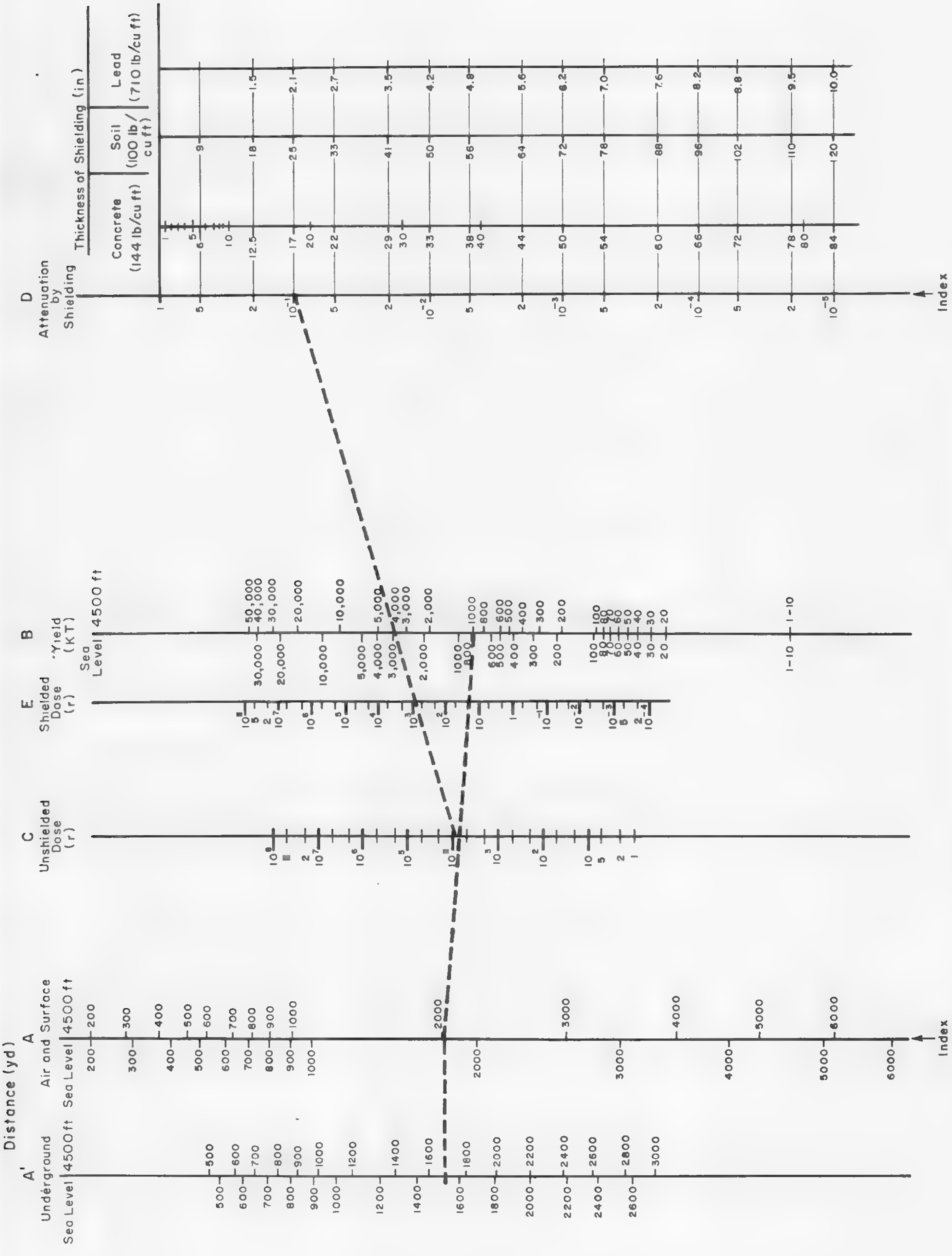
B. Underground Bursts

1. Use Axis A' (titled Distance-Underground). A horizontal line drawn from A' will intersect axis A at a point which can then be used for the remainder of the calculation.

2. Using the intersection on axis A found above, proceed as outlined for Air and Surface Bursts.

Note: It has been assumed that the shelter provided for instrumentation is shielded on all sides and on the top and that the dimensions of the shelter are small compared with distance required for significant attenuation of initial gamma rays in air.

Example: Distance represented 2000 yd from ground zero at 4500 ft alt. (or ~ 1800 yd at sea level; or for underground shot, ~ 1700 yd at 4500 ft and ~ 1550 yd at sea level). Line from axis A to 1000 kt (4500 ft) yield on axis B gives unshielded dose of ~ 8000 r on axis C. Line from Axis C to D (attenuation of 10^{-1}, representing 17 in. concrete, 25 in. soil, 2.1 in. lead gives shielded dose on axis E of ~ $8x10^2$ r.



5.4 Estimate of exposure to initial radiation

5.5. ESTIMATE EXPOSURE FROM RESIDUAL RADIATION

Directions

1. For any particular intensity of residual gamma radiation at H + 1 hour, two lines are drawn.

   a. Draw a line through Intensity on axis I and time of entrance (or arrival of cloud) on axis H + t.

   b. Draw a line through Intensity on axis I (same point as in a. above) and time of exit on axis H + t.

2. Extend both of the above lines to intersect axis D.

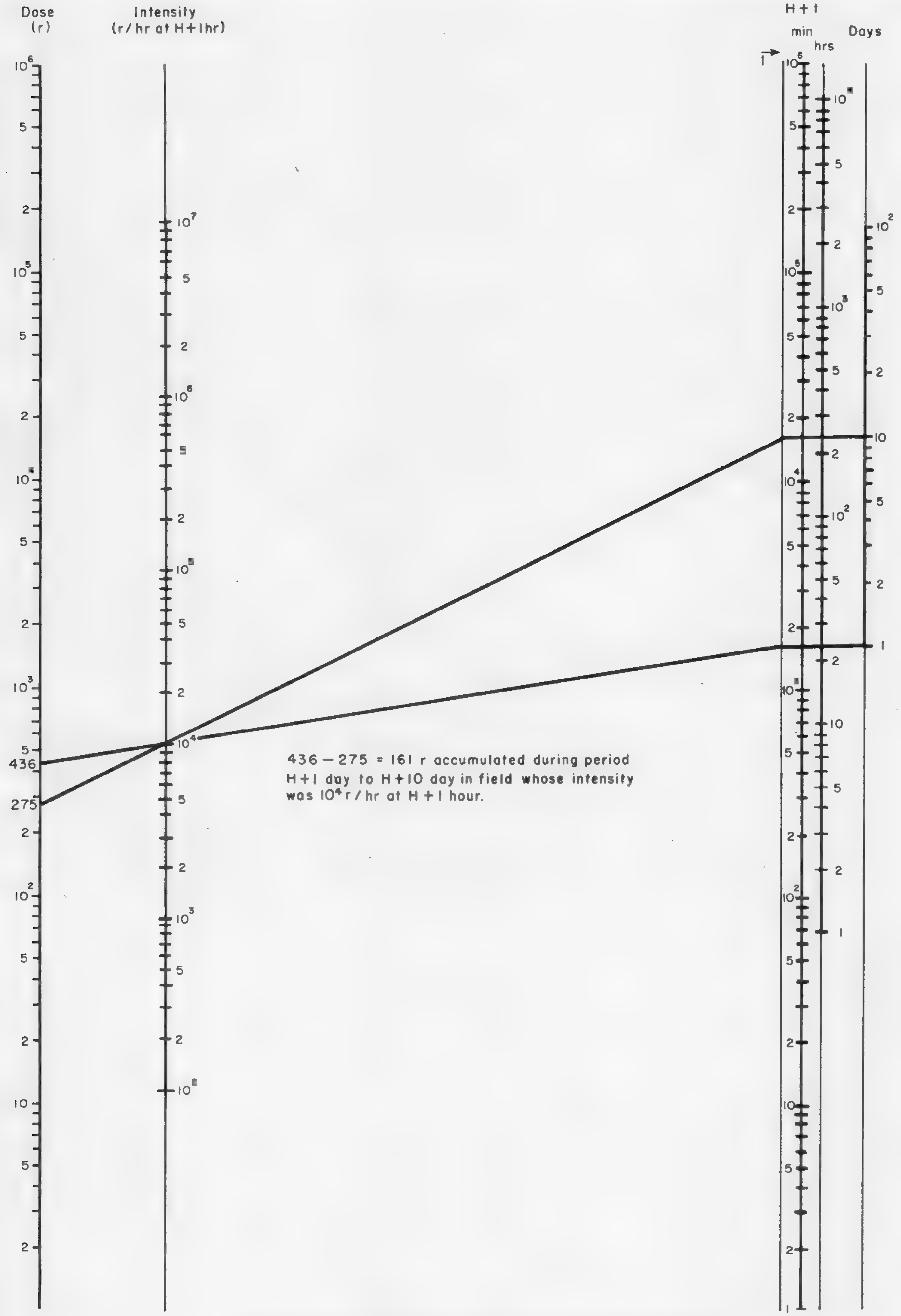
3. Subtract the numbers corresponding to the two points of intersection to find the dose received while in the radiation field.

4. For predictions of radiation exposures during field tests the nomograph is used with the following supplementary sources:

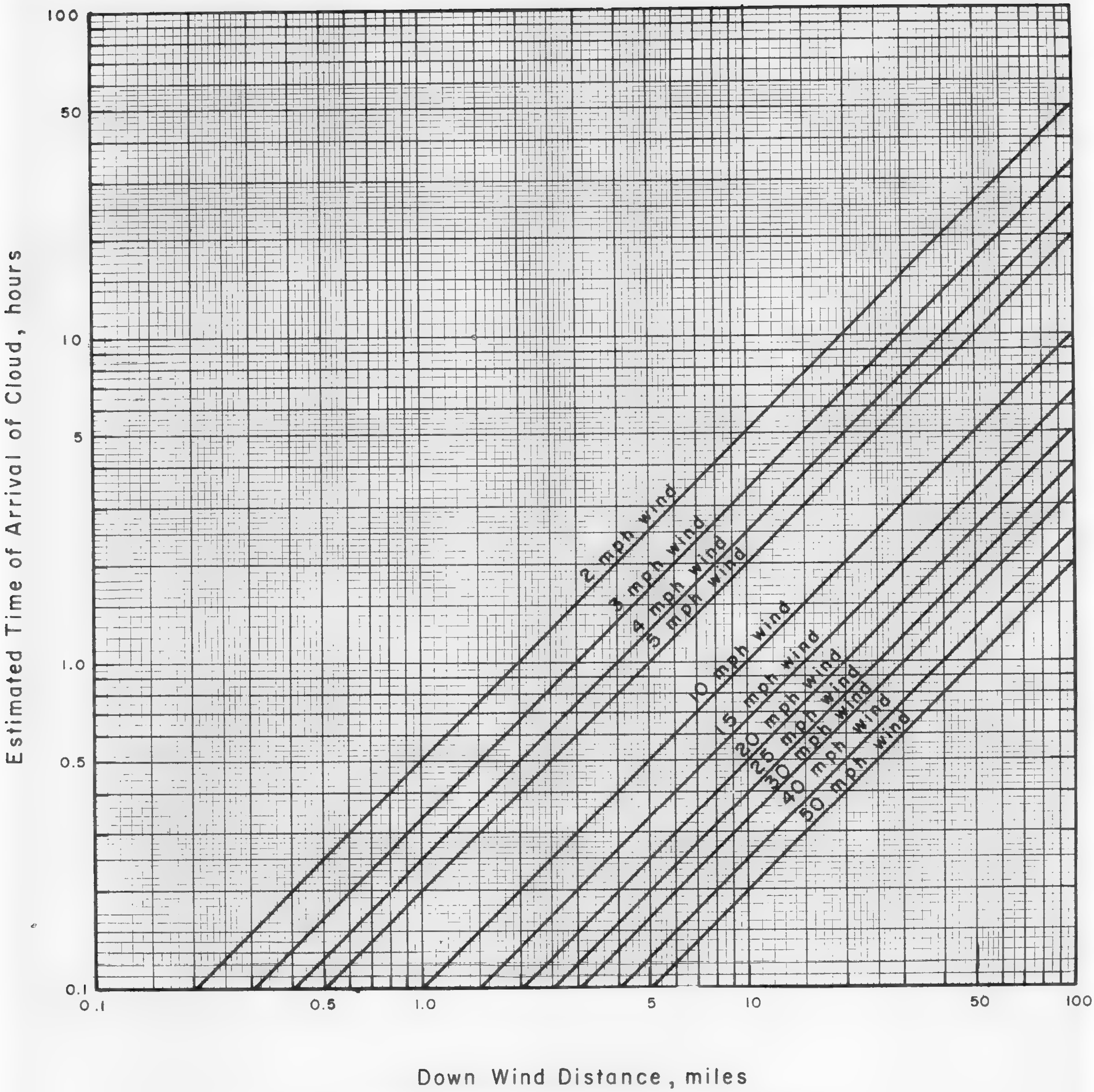
   a. Predictions of downwind dose rate contours such as those in TM 23-200, or those supplied by the task force. This will give H + 1 intensity at desired position.

   b. Graph of attenuation of residual gamma radiation. Multiplication of accumulated dose calculated with nomograph by attenuation factor for selected shielding thickness and material will provide estimate of expected exposure.

   c. For calculations of exposure to apparatus installed in area before blast and recovered later, the time of arrival of cloud should be used for time of entrance (see 1 above). This can be estimated from wind speed and downwind distance of station by using Fig. 5.6.



5.5 Estimate of exposure to residual radiation



5.6 Approximate downwind arrival time of fallout

TABLE 5.2 NUCLEAR PROPERTIES OF MATERIALS

Material	Atoms per cc x 10^{11}	Cross-Section in Barns			Percent absorbed per cm
		Slow neutrons	Maximum	Fast neutrons	
Aluminum	6.03	1.5b	10b	3b	10
Barium	1.53	10-18b	80b at 80 ev	6-12b	14
Beryllium	12.3	6-8 b		6b	
Cadmium	4.61	20-8kb		4-7b	25
Chromium	8.22	6-28b		3.5b	29
Cobalt	9.09	13-40b	7000b at 140 ev	3-20b	100
Copper	8.46	8-35b		2-6b	34
Germanium		10b	100b at 100 ev	3-10b	
Gold	5.89	30-450b	30kb at 5 ev	4.5-10b	43
Iron	8.48	10b		3.7b	42
Lead	3.30	10b		10b	33
Magnesium	4.31	3.5b	22b at 90 kev	5b	22
Manganese	7.89	4.5-20b	2000b at 300 ev	50b	100
Mercury	4.07	45-450b	500b at 34 ev	5-10b	30
Molybdenum	6.4	6.5-15b	900b at 40 ev	4-10b	
Nickel	9.13	25-30b	80b at 16 kev	6b	55
Oxygen	$5x10^{19}$	4-12b	14b at 0.44 mev	4b	
Platinum		10-20b	2kb at 12 ev	6-10b	
Selenium		10-60b	90b at 27 ev	3.5-10b	
Silicon	5.19	3b	11b at 0.2 mev	3b	
Silver	5.67	18-100b	12kb at 40 kev	4-7b	31
Tantalum	5.53	10-25b	13kb at 4 ev	5-10b	
Tin	2.92	2-5b	60b at 100 ev	4-7b	16
Titanium	5.64	4-10b	100b	5b	28
Tungsten	6.31	8-28b	14kb at 20 ev	5-10b	45
Vanadium		6-20b	70b	6b	
Xenon		10^4-$3x10^6$b			
Zinc	6.58	4b	140b at 500 ev	3-10b	36

Effects of radiation on some selected components are as follows:

Radar beacons and electron tubes. Gamma effects: (92, 000 r, 70, 000 r and 47, 000 r) no direct effects on units; measurable effects on quartz crystals; main damage is mechanical, only small changes in frequency (Reference 26).

Insulators. In a field of 10^{11} gammas/ cm^2-sec, resistance between 5 feet of copper wire covered with 1/32 in. of insulation and a metal drum on which the wire was wound dropped immediately to 10^{11} ohms for polyethylene and 2 x 109 ohms for polyvinyl chloride. It is not unusual for an insulator to change resistivity by a factor of 10^3 in intense radiation fields (References 27 and 28).

Vacuum tubes. Generally resistant--with exceptions. Gamma radiation can produce a number of stray electrons; sometimes radiation will produce a gassy tube. Can be af-

17. Ground Motion Produced by Aboveground Nuclear Explosions: Part I Predictions; Part II Summary and Correlation of Data, SRI Project SU-2206, for AFSWC, Interim Technical Report No. 1, May 15, 1958 (SRD)

18. Water-Wave Measurements, SIO/ONR, Operation Redwing, WT-1308, 1957 (SRD)

19. Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation, DOFL, Operation Plumbbob, ITR-1436, 1957 (SRD)

20. Waveform of Electromagnetic Pulse from a Nuclear Detonation, Operation Hardtack, ITR-1638 (SRD)

21. A Survey of Electromagnetic Effects, Observed during Upshot, UCRL, Operation Upshot-Knothole, WT-797, 1954 (SRD)

22. Supplementary Pressure Measurements, DTMB, Operation Upshot-Knothole, WT-777, 1954 (CRD)

23. Investigation of Early Electromagnetic Signals, LASL, Operation Upshot-Knothole, WT-791, 1954 (SRD)

24. Title classified, NRL, Operation Plumbbob, ITR-1416 (SRD)

25. Loading on Simulated Buried Structures at High Incident Overpressures, AFSWC, Operation Plumbbob, WT-1406, 1957 (SRD)

26. Cowan, M., Slide Rule Fallout Calculator, Sandia Corporation Tech Memo 177-57 (51), July 1957 (U)

27. Shelton, R.D., Effects of Radiation on Electronic Components, Electronic Industries & Tele-Tech, 15, 9, (Sept 1956)

28. Coleman, J.H., and Bohn, D., A Method for Increasing the Electrical Resistivity of Insulators to Ionizing Radiation, Jour. of Appl. Phys. 24, 4, (April 1953)

29. Pfaff, E.R., and Shelton, R.D., The Effects of Nuclear Radiation on Electronic Components, Phase 1, Scientific Report no. 1, Admiral Corp., October 10, 1955

30. Fowler, J.F. and Farmer, F.T., Conductivity Induced in Insulating Materials by X-rays, Nature, 143, 4398, (1954)

31. Miglicco, P.S., Radiation Effects on Electronic Components, Convair, Ft. Worth F2M-915, May 1, 1957 (U)

32. Ryan, J. W., Effect of Pile Radiation on Electrical Insulation, Modern Plastics, April 1954.

33. Morgan, H. L., Designing Electronics to Resist Nuclear Energy, Electronics, 30, 5 (May 1957)

34. Harwood, J.J., and others, The Effects of Radiation on Materials, Reinhold Publishing Corp., N.Y., 1958.

35. Effects of Nuclear Explosions on Fighter Aircraft Components, WADC, Operation Teapot, WT-1135, 1956 (SRD)

36. Transient Drag Characteristics on Spherical Models, BRL, Operation Teapot, WT-1114, 1956 (CRD)

37. Blast Loading and Response of Underground Concrete-Arch Protective Structures, WES, Operation Plumbbob, ITR-1420, 1957 (C)

38. Capabilities of Atomic Weapons, Department of the Army, TM-23-200, revised edition, July 1955 (SRD)

39. Neutron Flux Measurements, CRL, Operation Redwing, ITR-1313, 1956 (SRD)

40. Characterization of Fallout, NRDL, Operation Redwing, ITR-1317, 1956 (SRD)

41. Nuclear Radiation Handbook

42. Ground Acceleration, Stress, and Strain at High Incident Overpressures, SRI, Operation Plumbbob, ITR-1404, 1957 (CTRD)

43. Benderly, A. A., Shock Proof Packaging of Subminiature Vacuum Tubes, Shock and Vibration Bulletin, No. 24, February 1957, Office of Secretary of Defense, Research and Development (U)

44. Robbins, J. D., Recording Transients of Electron Tubes under High Impact Shock, Shock and Vibration Bulletin, No. 24, February 1957, Office of Secretary of Defense, Research and Development (C)

TABLE 6.2 CROSS-SECTIONS FOR TOWER HEIGHTS

Tower height (ft)	Peak drag pressure $\bar{=} p_{do}$ (lb/in.^{2})	Positive-phase duration (msec)	Drag coefficient $= C_d$	For Recommended Section: Fixed-end dynamic moment $= M_D$ in.lb.x10^3	Recommended Two-Pipe Section: Pipe O.D. (in.)	Pipe Wall thick. (in.)	O. C. spacing (in.)	Width of 1" plate (in.)
3	80	380-470	1.50	1,622	8-5/8	.322	16	12
5	350	300	1.50	17,000	8.0	1.500	24	20
5	80	380-470	1.50	4,128	8-5/8	.500	16	12
5	20	600	1.50	1,045	8-5/8	.322	16	12
10	150	300	1.50	30,210	9.0	2.000	27	23
10	80	380-470	1.50	14,465	8.0	1.250	24	20
10	20	600	1.50	4,862	8-5/8	.500	16	12
40	10	700	1.05	15,435	8.0	1.500	24	20

The general conclusions concerning calculations of maximum dynamic bending moment at the base of the towers are as follows:

1. The practice of taking the maximum dynamic moment equal to double the maximum static moment is always on the conservative side. However, where t_d/T is less than about 3, this approximation is too conservative and the exact ratio of the maximum M_D/M_S should therefore be used.

2. Effects of damping were neglected. Had damping been considered, the amplitude of the variations in the dynamic moment would have decreased with time and the dynamic moment would probably approach coincidence with the static moment as $t + t_d$.

M_D = dynamic bending moment at fixed-end of tower

M_S = maximum static-fixed end moment

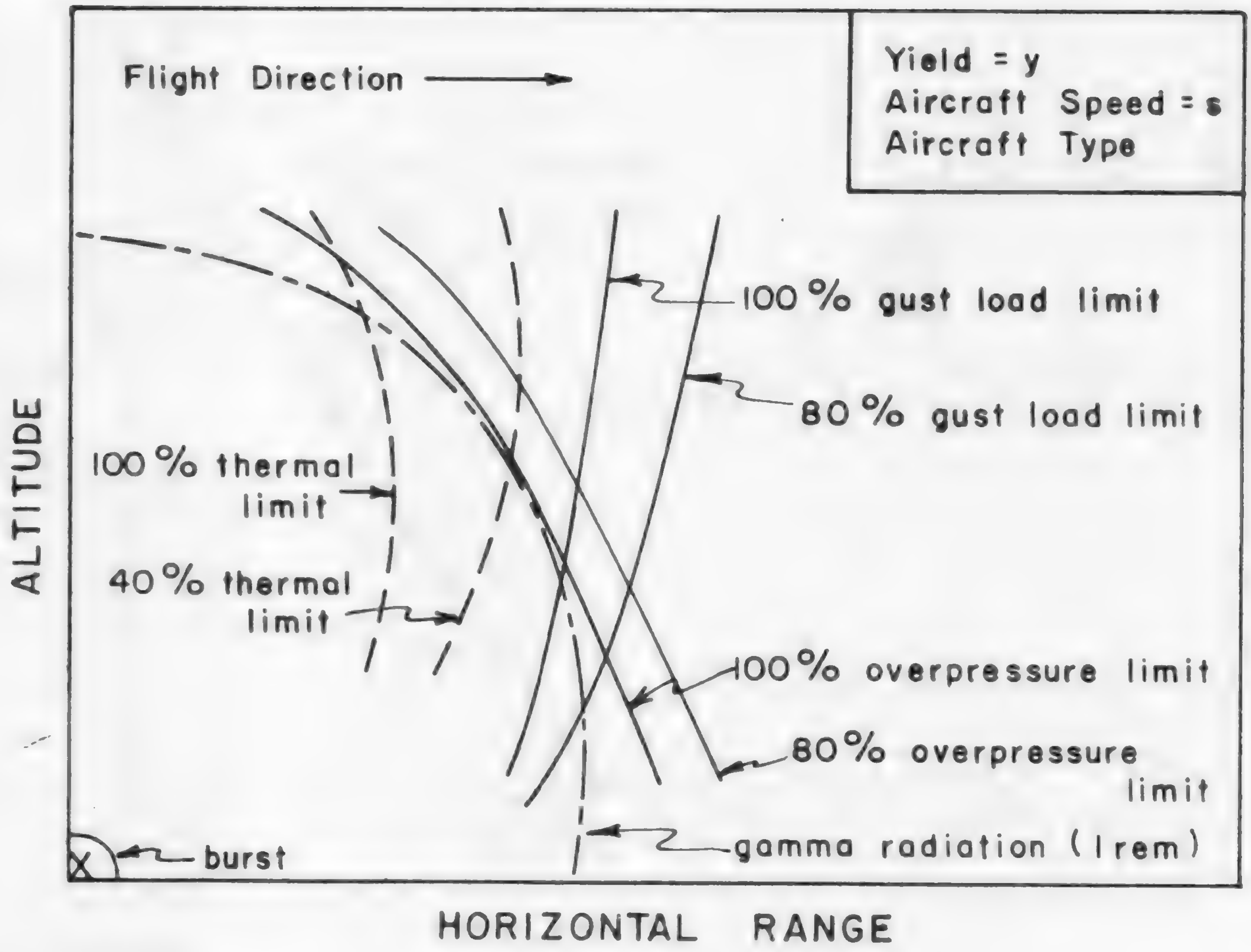
t = time

T_1 = fundamental natural period of vibration of tower (T)

t_d = effective duration of drag pressure (taken as $t_o/2$)

t_o = duration of positive phase of blast wave

3. For the size instrument mounts considered in this design their contribution to the total dynamic moment could be neglected without serious error. "A" frame steel configuration has been used successfully as mounting towers for instrumentation (NRDL)(Fig. 6.8).



8.3 Danger region diagram

Project officers are required to keep a running record of the cumulative exposure of their personnel to facilitate Rad-Safe control.

Rad-Safe does not register film badge readings less than 35 milliroentgens (mr). A considerable dose can thereby be built up by successive reentry if film badges are turned in after every reentry. This fact should be borne in mind, and personnel should note carefully their dosimeter readings and the radiation rate so that a film badge is turned in when it registers 35 mr or over.

In general, the time when fallout and residual radiation is most intense on the blast line is up to H + 2 hr; thus if the experiment plan is not seriously affected by entry after H + 2 hr, personnel burnout problems can be alleviated by the later entry.

RAD-SAFE

On-site radiation safety services include the following:

1. Continuing surveys and briefings of the radiological situation at the site.

2. Monitor training and monitoring assistance (if requested).

3. Issuance of film badges and monitoring equipment and maintenance of personnel dosimetry records.

4. Maintenance and issuance of protective clothing and equipment.

5. Decontamination facilities for personnel, vehicles, clothing, and equipment.

6. Registry of radioactive sources used or stored at site, and advice on preparation of radioactive materials for shipment from site.

In Nevada, the DOD Test Group has a Rad-Safe coordinator who acts as liaison officer with the Rad-Safe advisor to the test director and on-site Rad-Safe Group (REECO). In the Pacific, TG 7.1 maintains its own Rad-Safe function.

RECOVERY PROCEDURE

Several days before the shot in which a project is scheduled to participate, the program director calls for "event cards" from each project. On these cards are listed the project's button-up and recovery party, area of operation, time of entry and departure on D-1, or D-2 if EPG, time of reentry and departure postshot. From these event cards, an operations plan is made for the test group director and the test director's organization.

10.1 Postshot damage survey team, EPG

Rad-Safe Surveys

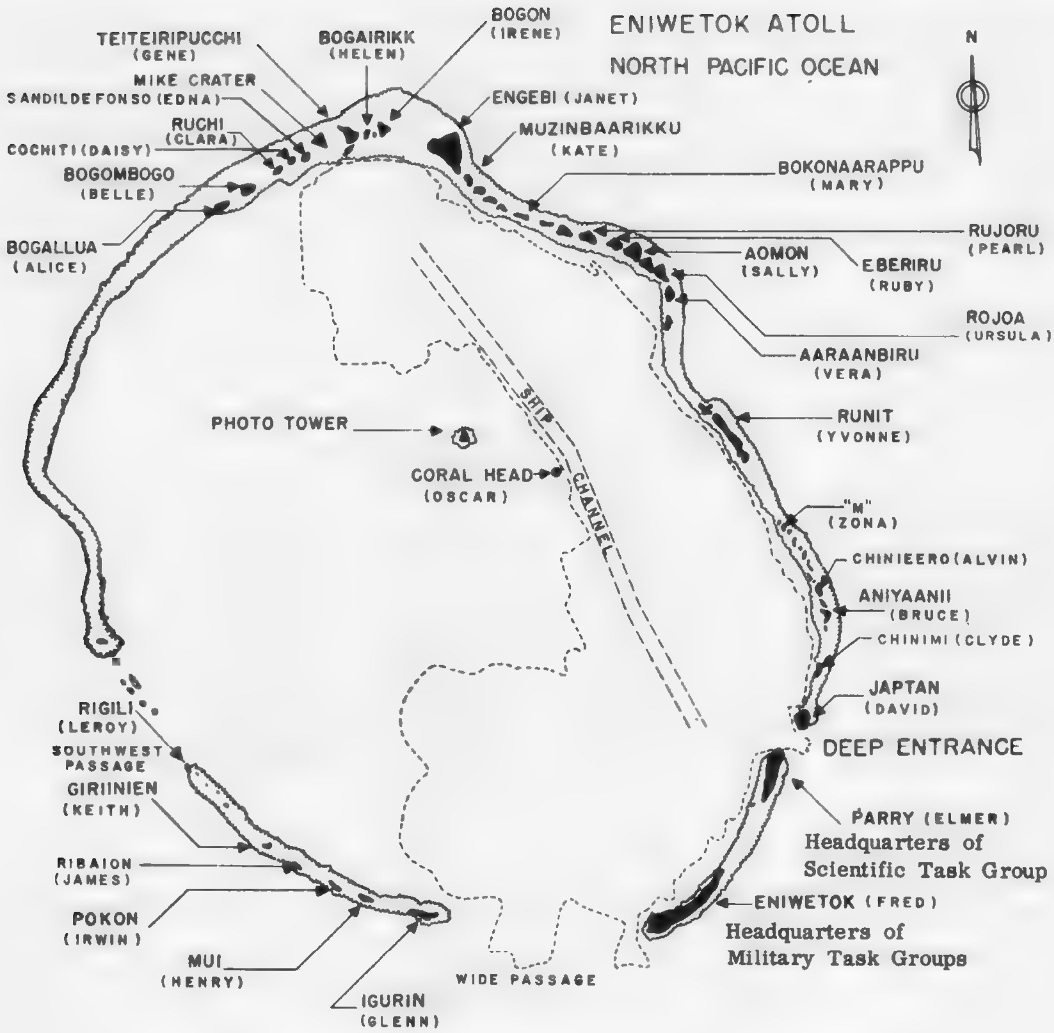
Rad-Safe surveys are begun at about H + 15 minutes, and the results of these surveys are posted in designated places at the site to indicate the intensity and extent of radiation. They are kept up-to-date for the remainder of the operation. When the radiation reaches a safe level, R-hour, or reentry time, for those not requiring early entry, is proclaimed. Areas are designated as follows:

Radex: radiological exclusion area.

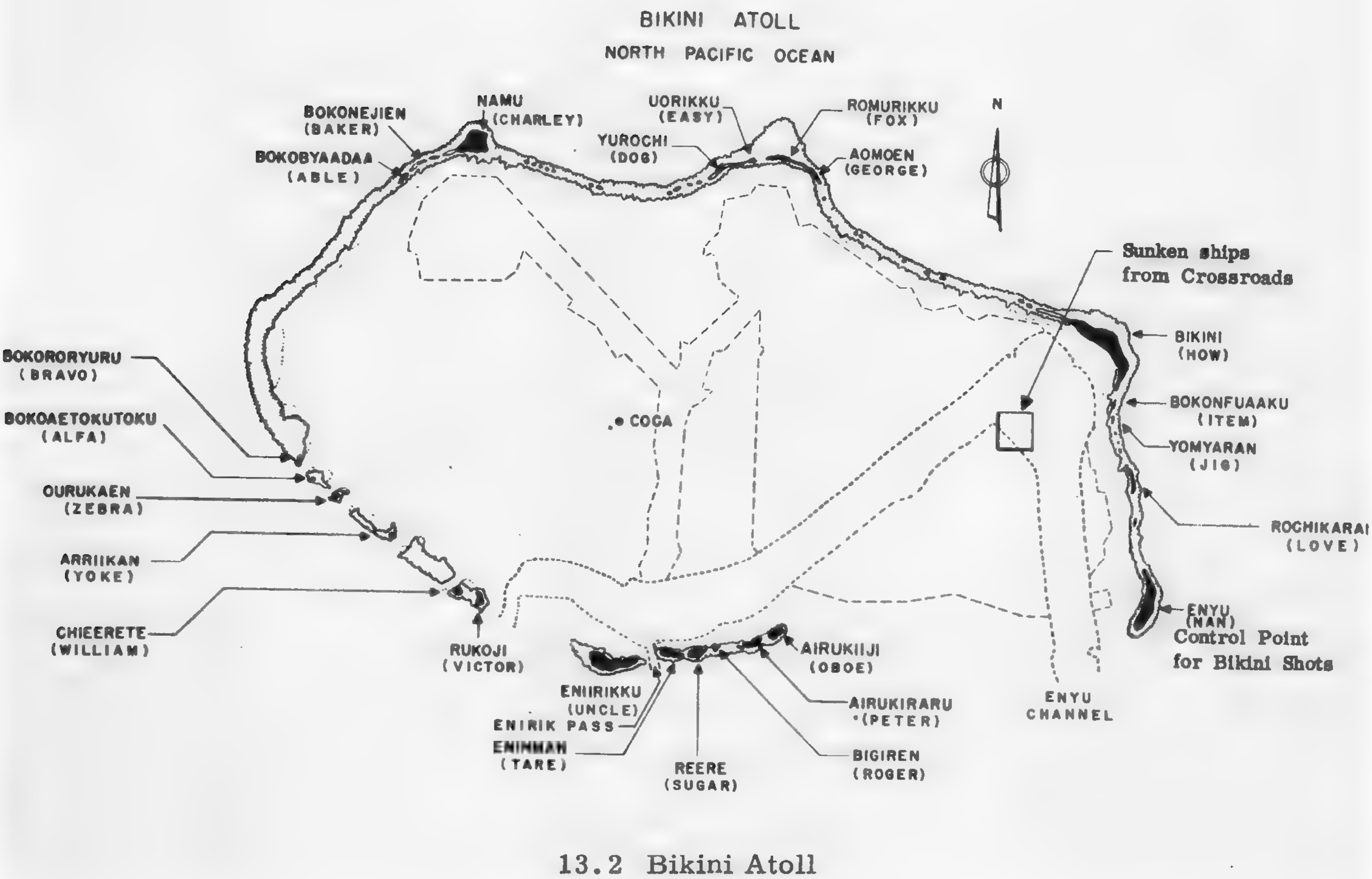
Full Radex: an area in which the radiation contamination exceeds 100 mr/hr gamma.

Limited Radex: an area in which radiation intensity is between 10 and 100 mr/hr gamma.

Recovery parties are seldom allowed in high intensity fields (greater than 10 r/hr).



13.1 Eniwetok Atoll



13.2 Bikini Atoll

13.7 Typical EPG terrain (Bikini), pisonia grove (top), palm grove (bottom)

13.11 Typical EPG terrain (Bikini), preshot

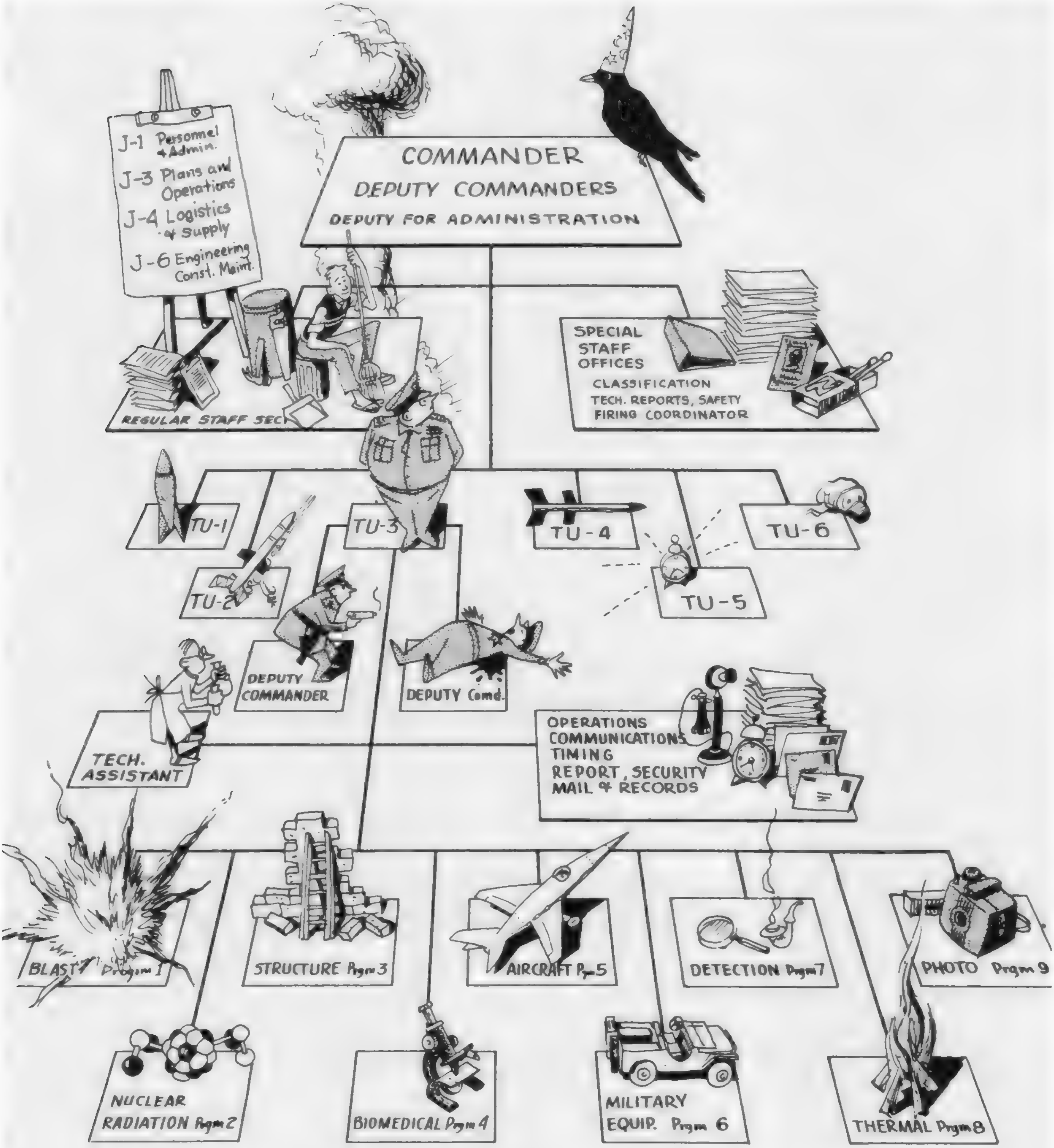
13.12 Typical EPG terrain (Bikini), postshot

TABLE 13A.1 MEAN WINDS ALOFT, ENIWETOK ATOLL, 1953 THROUGH 1957

Level (ft)	Direction (°)	Force (knots)	Std Vector Deviation* (knots)	No. Obs.	σ_x/σ_y	Level (ft)	Direction (°)	Force (knots)	Std Vector Deviation* (knots)	No. Obs.	σ_x/σ_y
APRIL						MAY					
9,843	090	9.3	10.6	457	1.41	9,843	095	9.8	9.2	462	1.32
19,685	074	5.5	13.9	458	1.52	19,685	092	1.9	11.7	459	1.46
29,528	272	8.3	22.7	457	1.77	29,528	266	12.1	16.7	454	1.49
39,370	260	21.4	25.9	453	1.39	39,370	260	25.9	23.4	442	1.40
49,212	281	18.6	23.3	421	1.61	49,212	274	25.3	22.7	423	1.32
59,156	030	5.0	15.5	340	1.59	59,156	046	3.0	13.1	366	1.36
68,897	086	9.1	14.6	301	2.22	68,897	093	15.6	14.5	318	2.14
78,739	092	18.0	23.0	274	2.37	78,739	092	26.7	21.8	275	2.88
88,582	091	25.3	28.6	215	3.01	88,582	091	34.4	26.4	223	2.80
98,424	092	30.9	30.8	123	2.32	98,424	093	39.1	28.0	123	3.12
JUNE						JULY					
9,843	097	12.8	9.0	397	1.44	9,843	096	12.6	8.5	418	1.34
19,685	089	9.0	10.8	393	1.60	19,685	093	8.5	9.9	410	1.02
29,528	325	0.5	15.4	381	1.44	29,528	283	0.7	14.0	400	1.16
39,370	256	12.5	19.5	373	1.20	39,370	267	8.0	21.5	394	1.12
49,212	273	15.1	18.8	344	1.35	49,212	259	11.4	19.8	368	1.10
59,156	085	13.1	12.2	263	1.69	59,156	093	19.1	12.0	306	1.55
68,897	092	25.7	14.6	235	1.81	68,897	091	29.8	15.8	276	2.33
78,739	092	35.7	23.2	211	3.85	78,739	091	39.6	22.1	245	2.58
88,582	093	45.5	24.9	158	3.13	88,582	092	49.4	23.8	198	2.51
98,424	091	43.0	28.6	78	2.26	98,424	093	53.6	23.8	96	1.67

* Computed for an equivalent circular distribution of vector variability.

σ_x/σ_y = ratio of std. devia. of east-west to std. devia. of north-south wind components; if the distribution is circular $\sigma_x/\sigma_y = 1$.

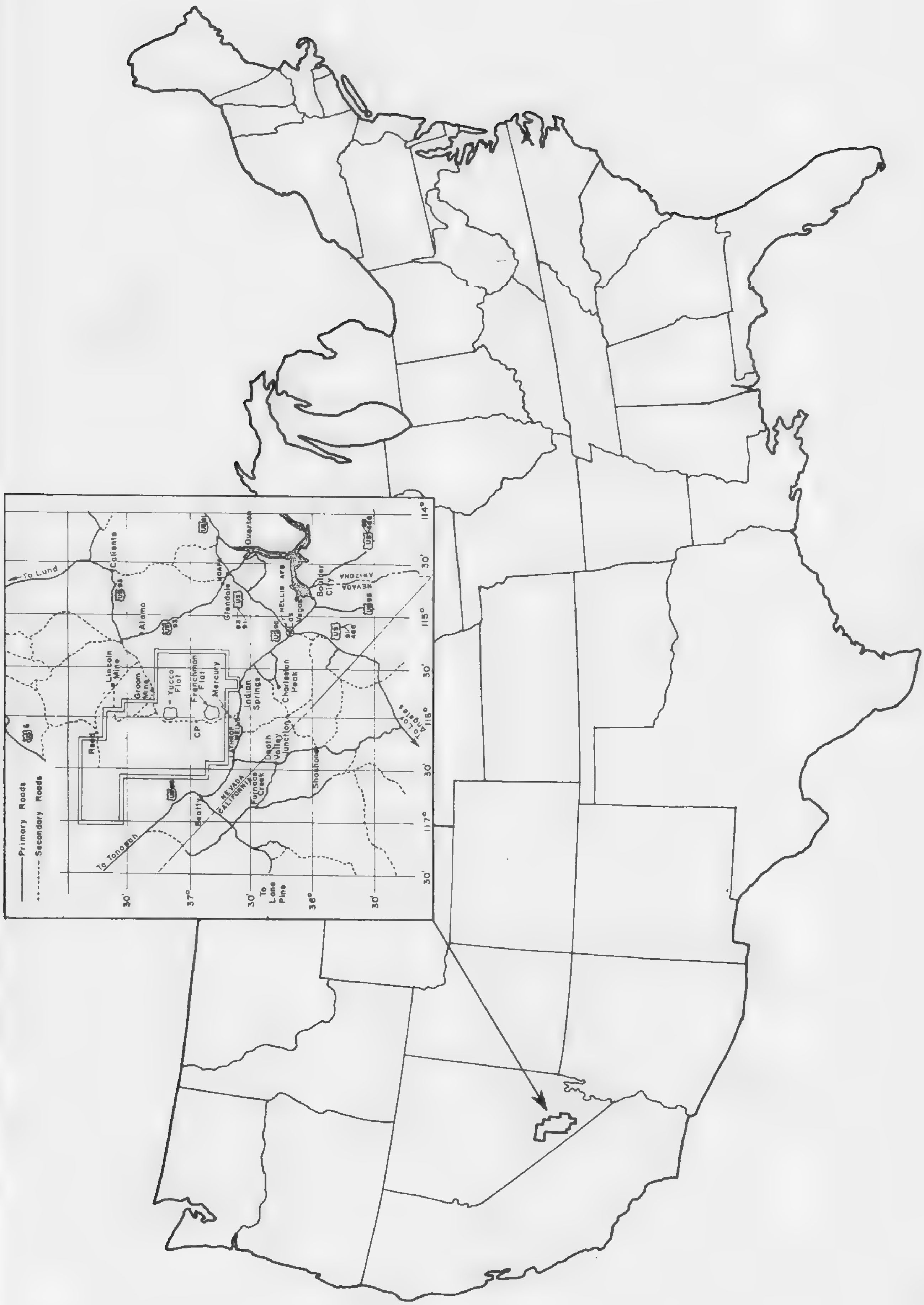


14.2 Organization of Task Group 7.1

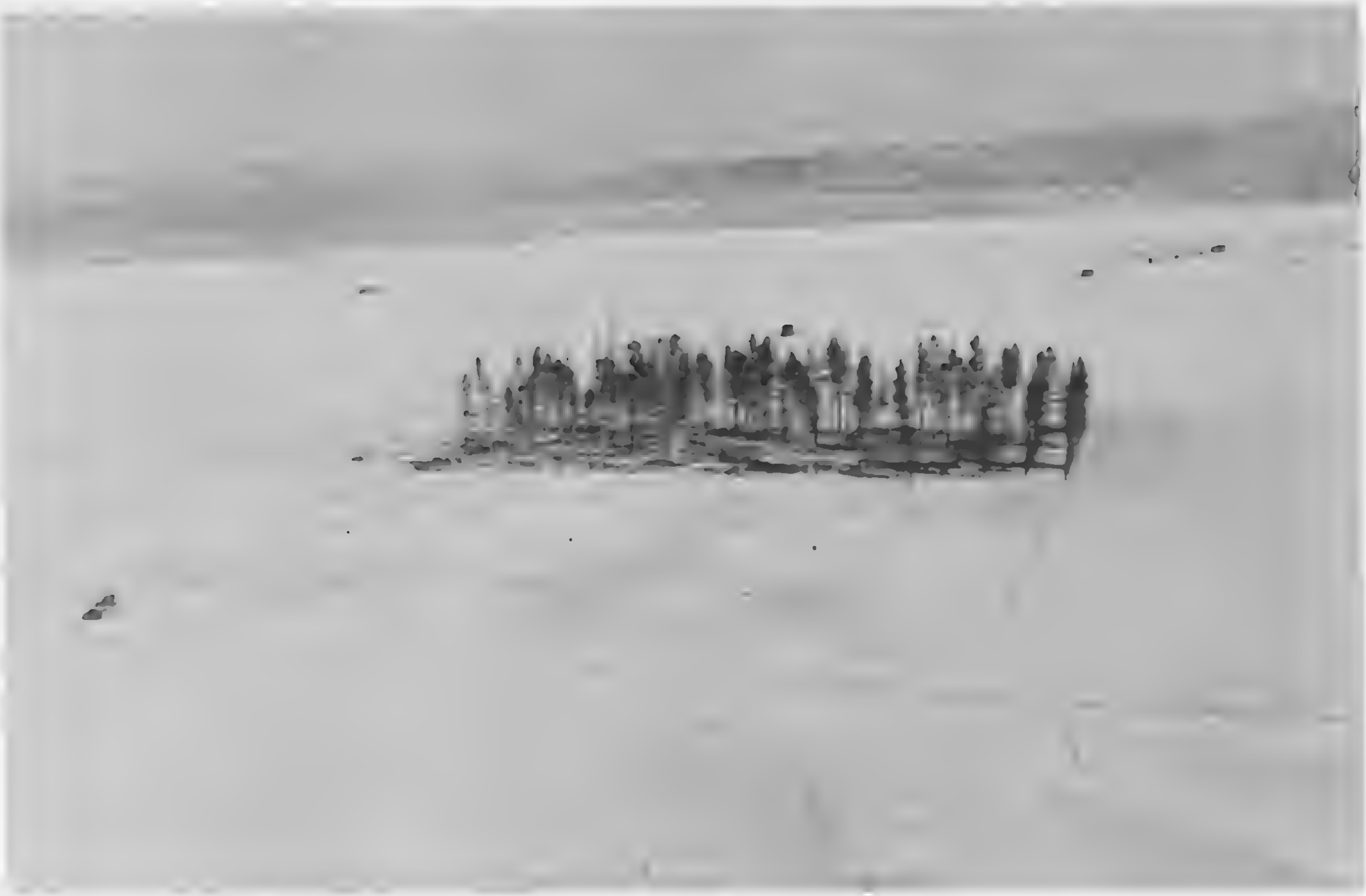
TABLE 17.1 POPULATION BREAKDOWN BY ATOLL*

Ailinglaplap	1,304
Ailuk	390
Arno	978
Aur	472
Ebon	745
Jaluit	1,154
Kwajalein (incl. Ebeye)	1,278
Kili Island	201
Lae	104
Likiep	596
Lip Island	63
Majuro	2,294
Maloelap	510
Mejit Island	245
Mille	361
Namrik	533
Namu	420
Ronglap	174
Ujae	180
Utrik	186
Wotho	47
Wotje	380
Ujelang	193
Approximate total	12,808

* Compiled April 1956

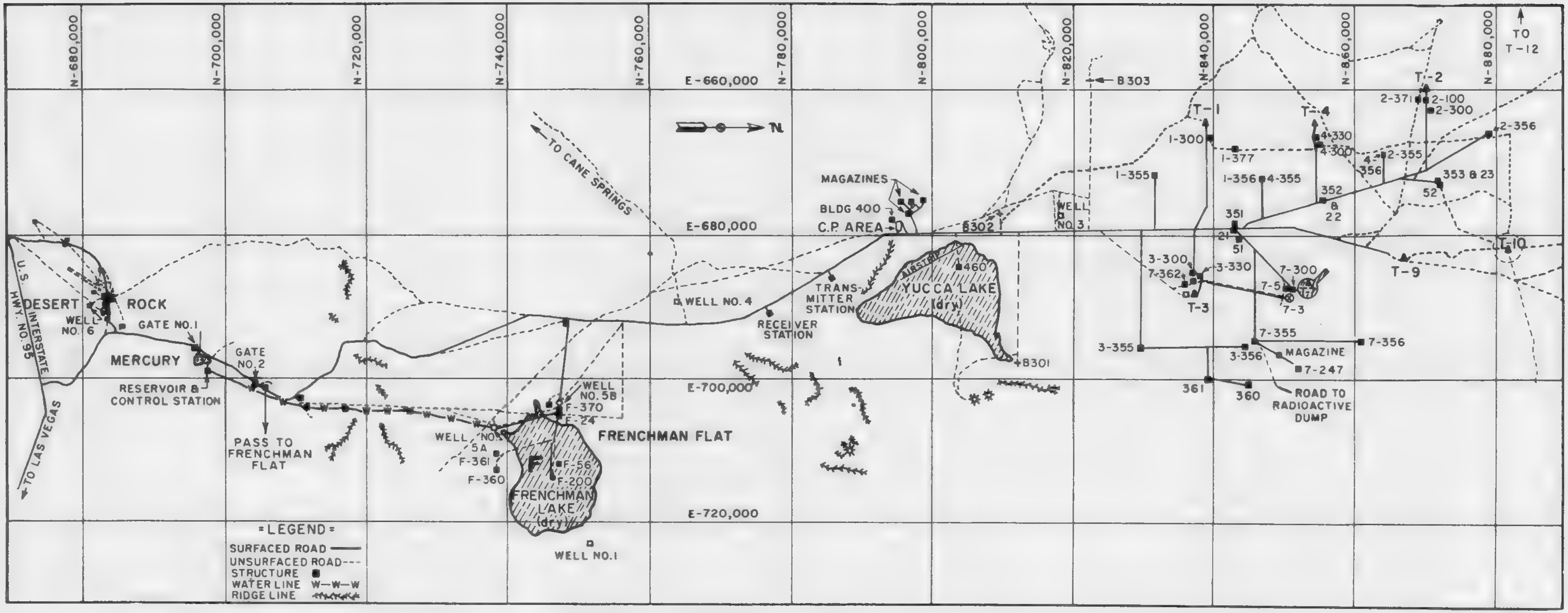


18.1 Location of Nevada Test Site



18.2 Typical terrain, Frenchman Flat (tree stand is atypical)

18.3 Typical terrain, Yucca Flat (overlooking Control Point, heliomat, and playa of dry lake--Joshua trees foreground are typical)



18.7 Layout, NTS

Supplement 18A
STANDARD TREATMENT OF SNAKE BITES AND SCORPION STINGS

SNAKE BITES

Immediate Treatment

Tourniquet. Apply the tourniquet lightly, just denting the skin, about six inches above the bite or area of swelling, if the bite is on an extremity.

Incisions. Incision or cutting of the fang marks is not advisable for by the time this can be done the venom has spread upwards and around the bite. The incisions or cuts should be about 1/8-inch deep and about 1/2-inch apart, just ahead of the swelling. Suctions should then be applied to the cuts and this should be repeated time and again. As the swelling advances another circle of incisions should be made about 3-inches from the preceding ring of cuts. Then repeated suction should be applied to this new ring of cuts. If the swelling continues to advance, similar rings of incisions should be made and repeated suction done. ADVANCE THE LIGHTLY PLACED TOURNIQUET AHEAD OF THE SWELLING AND INCISIONS. As the swelling advances the tourniquet is advanced and the incisions are made between the tourniquet and the line of swelling.

Warning

The individual bitten must not get excited and run. He should get away from the snake and then sit down and immediately apply a tourniquet, which in an emergency may be a tie, belt, or handerkerchief. Then either wait for help, or if in an isolated area, proceed as quietly and with as little effort as possible to your nearest transportation and nearest Aid Station. If you do not have a snake bite kit available, emergency treatment will be given at the Aid Station and immediate transportation provided to the NTS Dispensary at Mercury. If you have a snake bite kit, carry out the above instructions by applying the light tourniquet and then the first ring of incisions. After this proceed to your nearest Aid Station.

SCORPION STING

A scorpion sting is accompanied by a sharp, burning pain and an area of numbness around the puncture. In cases of a severe reaction, the victim may develop slurred speech and difficulty in breathing. He may become drowsy. Pain may be excruciating. Proceed to the nearest Aid Station for the following treatment.

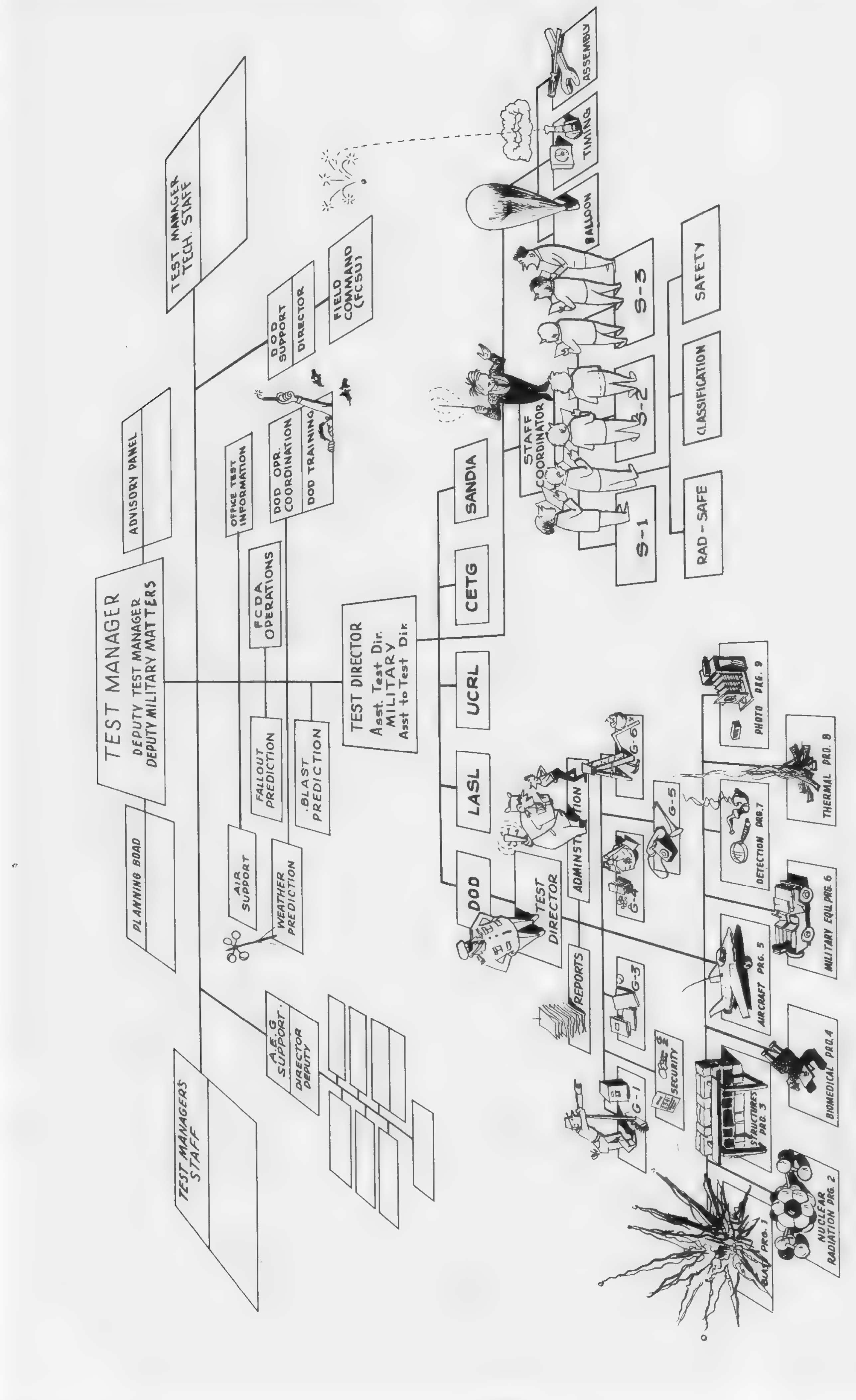
Treatment

As soon as possible apply ice wrapped in a cloth, or an ice bag, to the sting. Morphine sulfate 1/4 to 1/2 grain given intramuscularly. DO NOT GIVE DEMEROL. Local pain may be controlled by the local injection of Procaine or Novocaine. Convulsions may be controlled by the injection of Luminal Sodium or Pentathol Sodium. Antivenin, if available, may be used.

TABLE 18.3

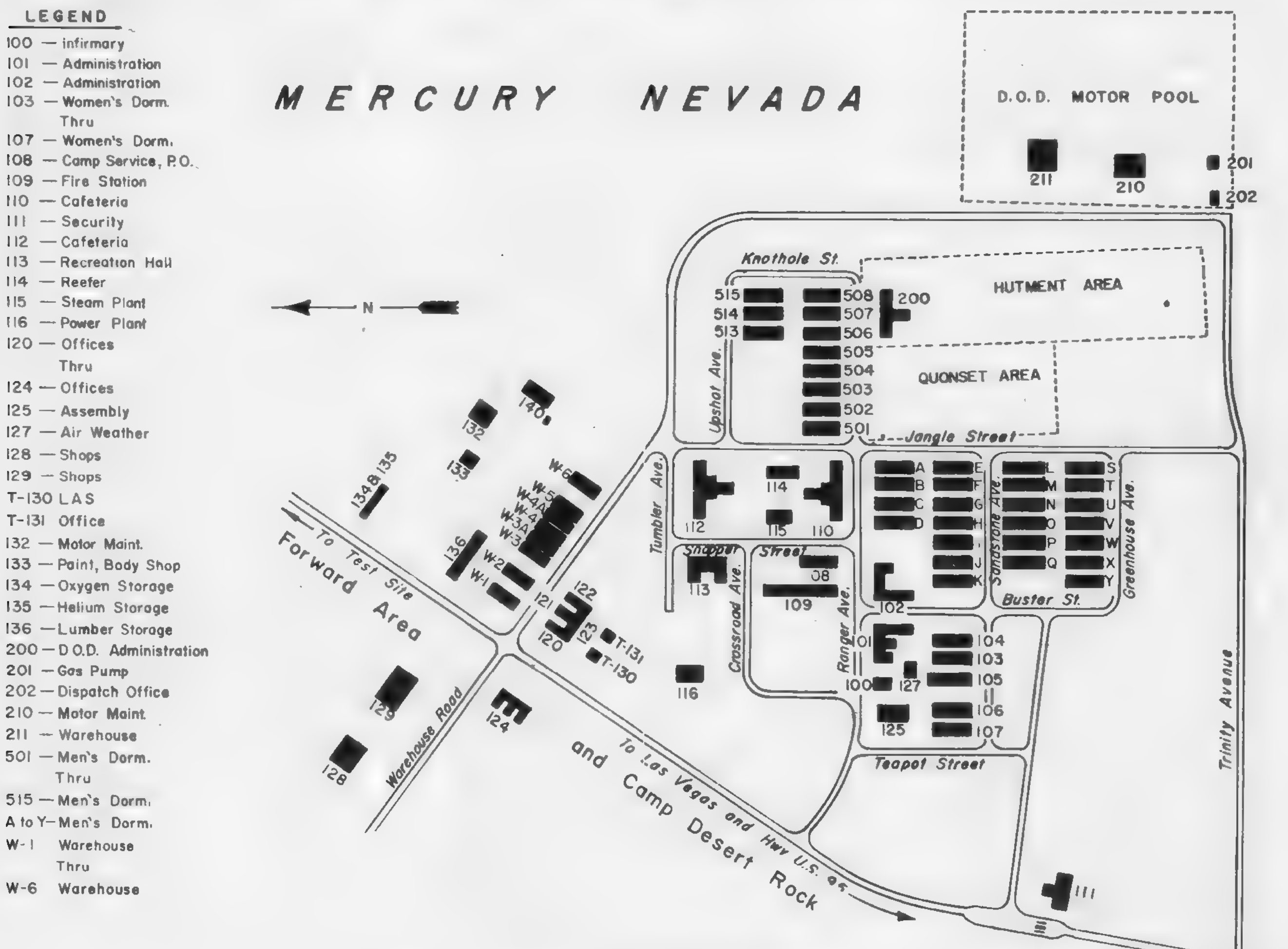
PERCENTAGE FREQUENCY OF WINDS BY DIRECTION AND SPEED
(From Five Years of Las Vegas Soundings)
500 Millibars (18,000 Feet, MSL)
0700 PST

	Speed (mph)	Direction																All Directions
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Jan-Feb	1-19	1.0	1.0	0.3	0.3	0	0	0.7	0	0.7	0.3	0.3	1.0	0.7	2.0	1.3	0.3	10.0
	20-29	4.3	1.0	0	0	0	0	0.3	1.0	1.0	1.3	3.0	4.7	7.0	4.0	4.7	3.0	35.3
	40-59	1.0	1.3	0.7	0	0	0	0.3	0	0	1.3	2.7	5.7	6.0	5.7	3.3	2.3	30.3
	60-99	1.3	1.0	0	0.7	0	0	0	0	0.3	0	4.3	4.0	2.3	3.3	2.0	2.3	21.7
	>100	0	0	0	0	0	0	0	0.3	0	0.7	0.7	0.3	0	0	0.3	0.3	2.7
	All Speeds	7.7	4.3	1.0	1.0	0	0	1.3	1.3	2.0	3.7	11.0	15.7	16.0	15.0	11.7	8.3	100.0
Mar-Apr	1-19	1.0	1.6	1.0	0	0	0.7	0.3	0.7	0.3	1.3	0.3	1.6	1.6	2.3	1.6	1.3	15.6
	20-39	2.6	1.0	1.3	0.3	0	0.7	1.0	0	0.7	1.9	3.2	5.7	6.8	6.5	4.2	3.3	39.3
	40-59	1.6	0.3	0	0	0	0	0	0.3	0.7	2.3	3.9	4.2	5.8	2.9	3.6	1.6	27.3
	60-99	1.9	0	0	0	0	0.3	0	0	0.7	1.0	2.3	3.2	2.3	1.9	2.3	1.9	17.5
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3
	All Speeds	7.1	2.9	2.3	0.3	0	1.6	1.3	1.0	2.3	6.5	9.7	14.6	16.9	13.6	11.7	8.1	100.0
May-June	1-19	0	2.6	2.0	0	0.7	0.7	1.3	0.7	1.6	3.0	2.6	1.0	3.6	2.3	2.3	3.6	28.1
	20-39	0.3	0.7	0.7	0	0	0.3	0.3	0	1.6	2.3	8.6	7.0	7.0	3.6	3.0	4.0	39.5
	40-59	1.3	0	0	0	0	0	0.3	0	1.0	5.6	6.6	3.3	3.3	3.0	1.0	0.3	25.8
	60-99	0	0	0	0	0	0	0	0.3	0.7	1.3	1.0	1.3	0.3	0.3	1.0	0	6.3
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3
	All Speeds	1.6	3.3	2.7	0	0.7	1.0	2.0	1.0	5.0	12.2	18.9	12.6	14.5	9.2	7.3	7.9	100.0
July-Aug	1-19	0.3	0.7	1.9	1.9	1.6	1.6	3.3	5.5	4.5	6.3	8.4	7.7	3.9	2.9	0.7	1.0	52.1
	20-39	0	0.3	0	0	0	0	1.9	1.9	4.2	8.0	12.5	7.7	1.9	1.9	0.7	0	41.2
	40-59	0	0	0	0	0.3	0	0	0	0.3	1.9	1.0	2.9	0	0	0	0	6.4
	60-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	All Speeds	0.3	1.0	1.9	1.9	1.9	1.6	5.2	7.4	9.0	16.2	21.9	18.3	5.8	5.2	1.3	1.0	100.0
Sept-Oct	1-19	1.6	1.3	1.0	1.3	1.0	1.7	2.3	1.7	4.0	2.7	4.0	3.0	3.6	3.3	2.0	1.7	36.1
	20-39	1.3	1.3	0.7	0.7	0.7	0.7	1.0	0.7	1.3	7.3	6.0	6.0	6.3	4.0	4.3	2.3	44.5
	40-59	0.7	0.3	0	0	0.3	0	0	0	0.7	1.7	3.6	4.3	2.0	1.3	0	0	14.9
	60-99	0	0	0	0	0	0	0	0	0	1.0	1.0	0.7	0	1.0	1.0	0	4.6
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	All Speeds	3.6	3.0	1.7	2.0	2.0	2.3	3.3	2.3	6.0	12.6	14.6	13.9	11.9	9.6	7.3	4.0	100.0
Nov-Dec	1-19	0.3	0.3	1.3	0.3	1.3	0.3	0.3	1.0	0.7	1.6	1.0	2.0	3.0	2.0	1.6	2.0	19.1
	20-39	2.0	1.6	0	0.3	0.7	0	1.0	0.7	1.6	1.3	2.3	3.6	7.9	4.9	4.0	3.6	35.5
	40-59	1.3	1.0	0	0	0	0	0	0.3	0.3	1.0	3.6	1.3	4.6	4.9	3.6	3.0	25.0
	60-99	1.6	0	0	0	0	0	0	0.3	0	0.3	2.3	3.6	3.3	3.3	2.0	3.0	19.7
	>100	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0.7
	All Speeds	5.3	3.0	1.3	0.7	2.0	0.3	1.3	2.3	2.6	4.3	9.2	10.8	18.8	15.1	11.5	11.5	100.0
200 Millibars (40,000 Feet, MSL)																		
Jan-Feb	1-19	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.7
	20-39	0.4	0	0	0.4	0	0	0.4	0	0.4	0.4	1.1	0.4	3.3	0.7	1.8	0.7	9.8
	40-59	0.4	0.4	0	0.4	0	0	0	0	0	0.4	2.5	1.4	7.6	7.6	4.3	2.2	27.0
	60-99	1.8	0.4	0.4	0	0	0	0	0	0	1.1	4.0	10.5	11.6	8.0	5.4	1.8	44.8
	>100	0.4	0	0	0	0	0	0	0	0.4	0.4	1.8	5.0	5.0	2.9	0.4	1.4	17.7
	All Speeds	2.9	0.7	0.4	0.7	0	0	0.4	0	0.7	2.2	9.4	17.3	27.8	19.2	12.3	6.1	100.0
Mar-Apr	1-19	0.3	0.3	0	0	0.3	0	0	0	0	0	0.3	0.3	0	0.3	0	0.3	2.3
	20-39	0.3	1.0	1.0	0	0	0	0	0	0.3	0.3	1.3	2.3	3.4	0.7	3.0	1.7	15.5
	40-59	1.7	0.3	0	0	0	0	0	0	0	0.7	2.0	4.0	6.4	4.7	3.0	1.3	24.1
	60-99	1.0	0	0	0	0	0	0	0	0	0.7	4.4	9.4	12.8	4.0	2.3	4.0	38.6
	>100	0.3	0	0	0	0	0	0	0	0	0	1.3	7.0	4.0	3.4	2.3	1.0	19.5
	All Speeds	3.7	1.7	1.0	0	0.3	0	0	0	0.3	1.7	9.4	23.1	26.6	13.1	10.7	8.4	100.0
May-June	1-19	0	0.3	0.3	0.3	0.3	0.7	0	0	0.3		0.3	1.0	0.7	0.7	1.3	0	7.0
	20-39	1.7	0.3	0	0	0	0	0	0.3	1.3	0.3	0.7	2.0	3.7	2.0	1.3	1.0	14.7
	40-59	0.3	0.3	0	0.3	0	0	0	0	1.3	1.7	2.0	5.0	7.4	4.0	2.0	1.3	25.8
	60-99	0.7	0.3	0.3	0	0	0	0	0	0.3	2.7	10.4	10.0	9.0	4.3	2.0	0.3	40.5
	>100	0	0	0	0	0	0	0	0	0.7	0.3	4.7	2.7	1.7	1.3	0.3	0.3	12.0
	All Speeds	2.7	1.3	1.0	0.7	0.3	0.3	0.7	0.3	3.7	5.4	18.1	20.8	22.4	12.4	7.0	3.0	100.0
July-Aug	1-19	0	0.3	0.3	0	0	0	0	1.0	0	0.3	0.3	1.6	0.3	1.3	0.3	1.3	7.2
	20-39	0	0	1.0	0	0.7	0.3	0.3	2.3	3.3	2.6	8.6	6.9	4.3	3.3	0	0.3	33.9
	40-59	0	0	0	0	0	0	0.3	0.7	1.6	4.6	11.8	10.2	6.9	1.6	0.3	0	38.1
	60-99	0.3	0	0	0	0	0	0	0	0.3	2.6	8.2	5.9	1.6	1.0	0	0	20.1
	>100	0	0	0	0	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0.7
	All Speeds	0.3	0.3	1.3	0	0.7	0.3	0.7	0.4	5.3	10.2	29.3	24.9	13.2	7.2	0.7	1.6	100.0
Sept-Oct	1-19	0.7	0	0	0	0.7	0	0.3	0	0.7	0.3	0.3	2.4	0	0.3	0.7	0	6.4
	20-39	0.7	0.3	0.3	1.0	0.3	0	0	0.3	0.7	1.0	4.4	3.7	5.4	5.1	3.4	1.7	28.5
	40-59	0.7	0	0	0	0	0	0	0.3	0	0	3.4	6.4	4.7	5 1	3.4	1.4	25.4
	60-99	0.7	0	0	0	0	0	0	0	0	0.3	6.4	9.8	9.5	4.4	1.4	0.3	32.9
	>100	0	0	0	0	0	0	0	0	0	0.3	1.7	3.7	0.7	0.3	0	0	6.8
	All Speeds	2.7	0.3	0.3	1.0	1.0	0	0.3	0.7	1.4	2.0	16.3	26.1	20.3	15.2	8.9	3.4	100.0
Nov-Dec	1-19	0.7	0	0	0	0	0	0.7	0.7	0	0.7	0.3	1.0	0.7	0.3	1.0	0.3	6.3
	20-39	0.7	0	0	0	1.0	0	0.7	0.7	0.3	1.0	2.0	1.3	2.0	1.0	3.0	1.7	15.2
	40-59	0.3	0	0	1.0	0	0	0	0.3	0.3	0	0.7	2.7	6.0	5.0	4.3	1.7	22.2
	60-99	0.3	0.7	0	0	0	0	0	0	0	0	4.0	6.6	12.3	7.3	5.0	2.3	38.4
	>100	0	0.3	0	0	0	0	0	0	0	0	0.7	7.0	2.7	4.3	3.0	0	17.9
	All Speeds	2.0	1.0	0	1.0	1.0	0	1.3	1.7	0.7	1.7	7.6	18.5	23.5	17.9	16.2	6.0	100.0

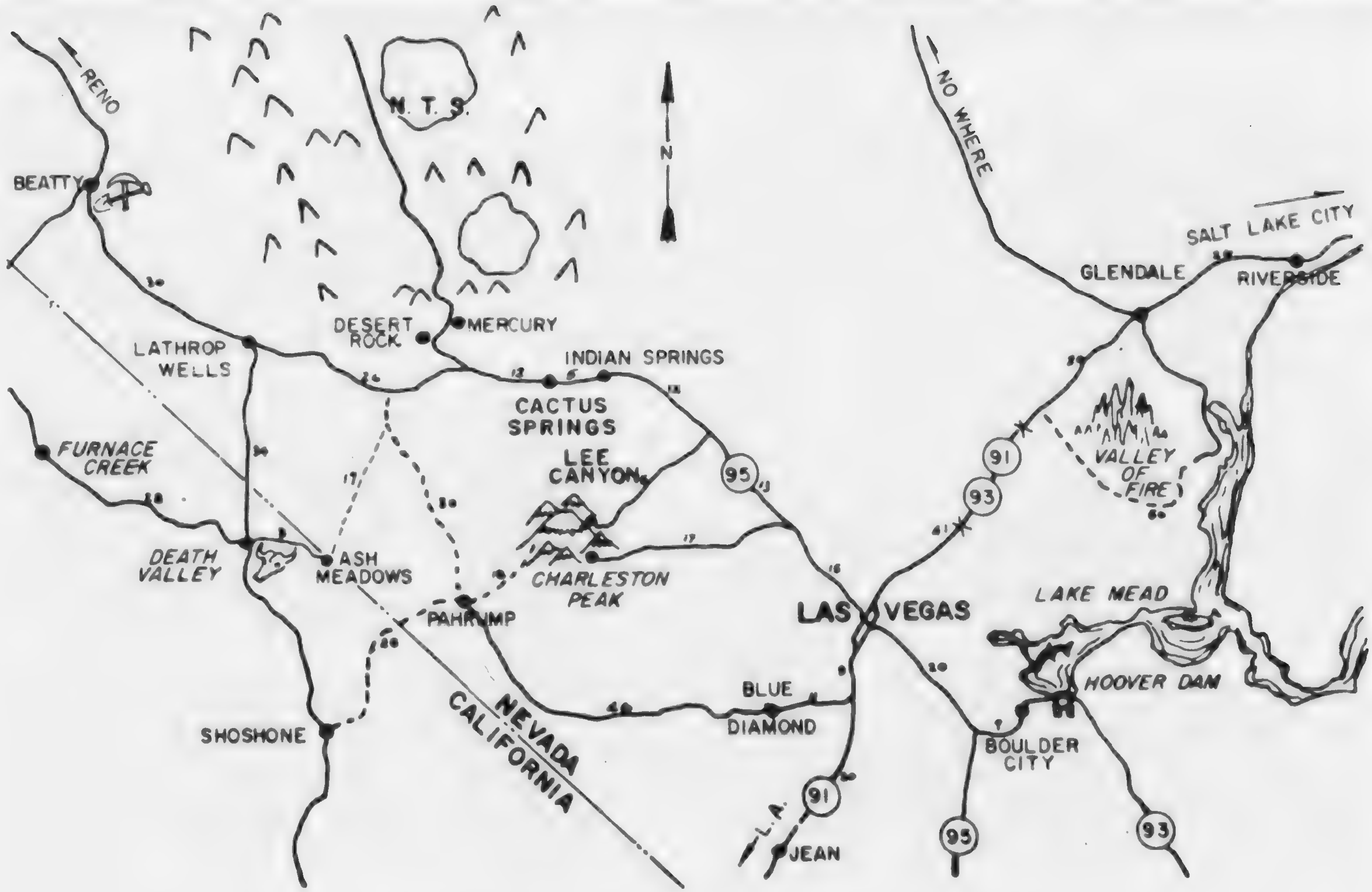


19.1 Nevada Test Organization

21.1 Aerial view, Camp Mercury (circa AD 1952)



21.2 Layout, Camp Mercury



21.3 Hither and thither from Mercury

PRINCIPLES OF RADIATION AND CONTAMINATION CONTROL

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E. J. LEAHY
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BUREAU OF SHIPS NAVY DEPARTMENT WASHINGTON 25, D. C.

prepared by

U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

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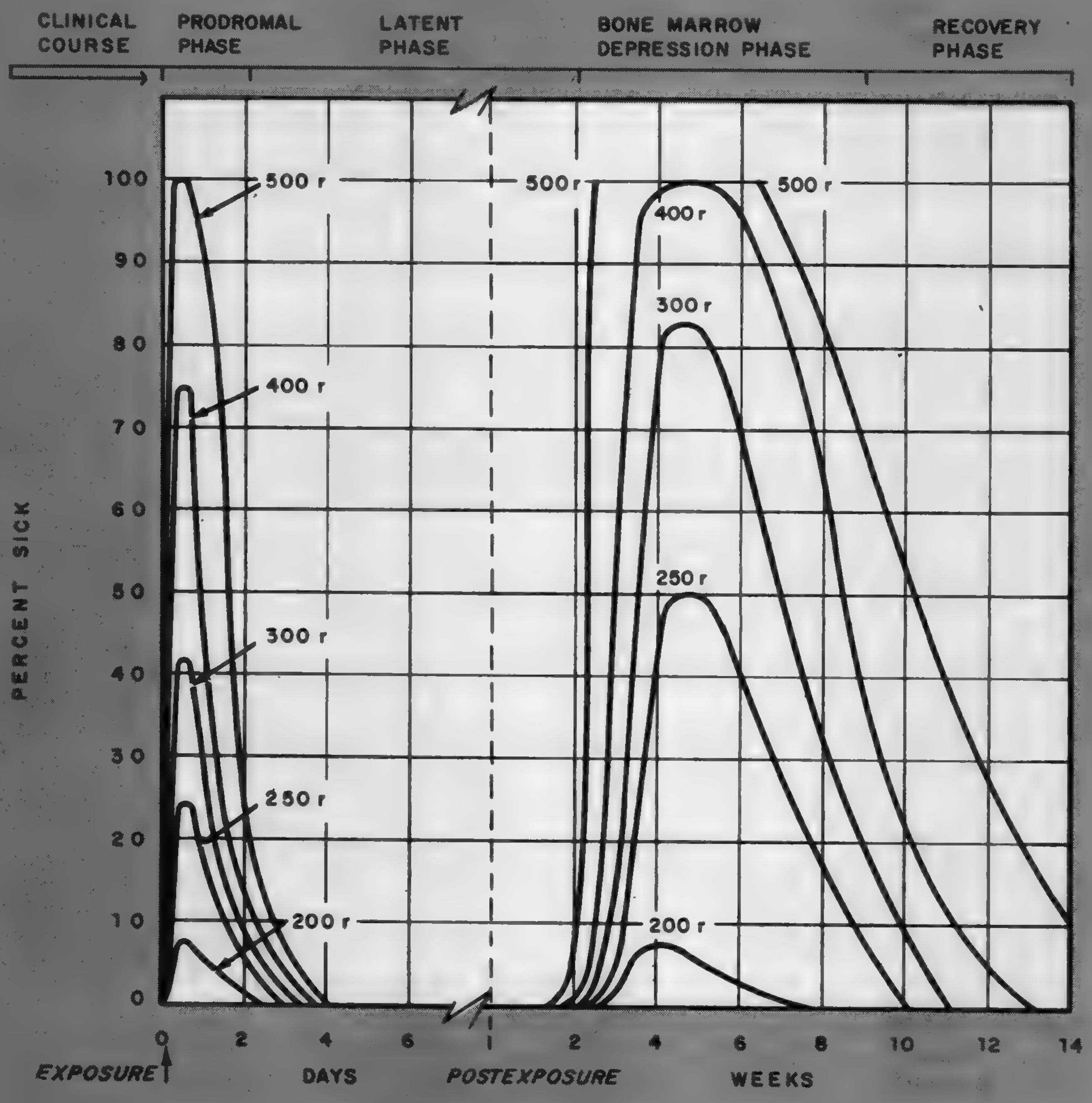


FIG. 1.2 ESTIMATE OF INCIDENCE AND DURATION OF SICKNESS FOR POPULATIONS EXPOSED TO VARIOUS AMOUNTS OF PENETRATING IONIZING RADIATION

TABLE 1.5

Acute Effects of Ionizing Radiation on Skin

Estimated Dose Required (EDR) in 1 week (rad)	Effect[1]
0-600	No acute effects.
600-2000	Moderately early erythema.
2000-4000	Early erythema before 24 hours. Skin breakdown in 2 weeks.
4000-10,000	Severe erythema in 24 hours. Severe skin breakdown in 1 - 2 weeks.
10,000-15,000	Severe erythema in 4 hours. Severe skin breakdown in 1 - 2 weeks.
15,000-100,000	Immediate skin blistering (< 1 day).

(1) For exposures extending over a period of more than a few hours, the temporal relationships will be modified somewhat from those shown. For example, a dose of 4000 - 10,000 rads given in 1 week will not produce severe erythema in 24 hours.

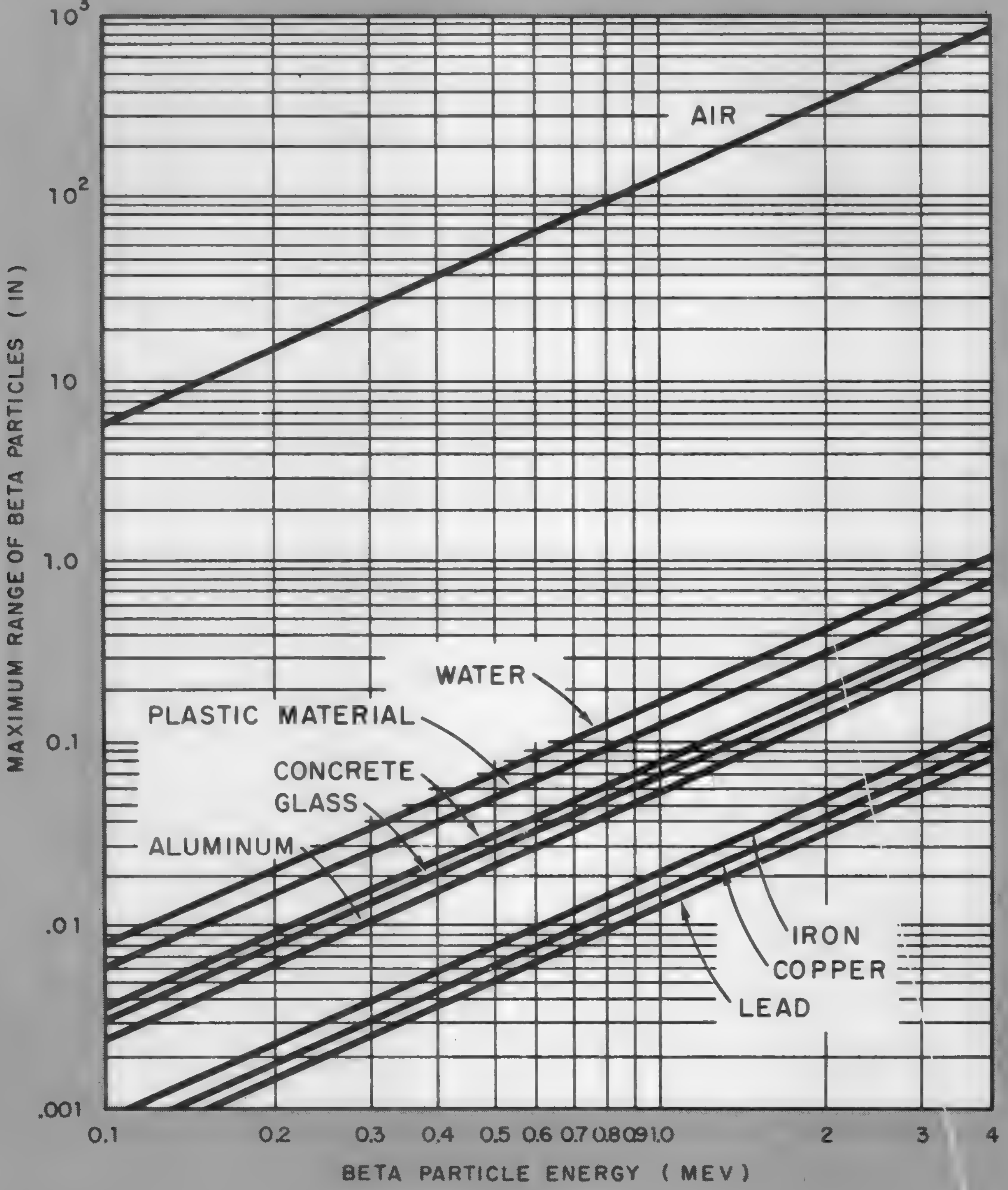


FIG. 2.5 PENETRABILITY OF BETA RADIATION

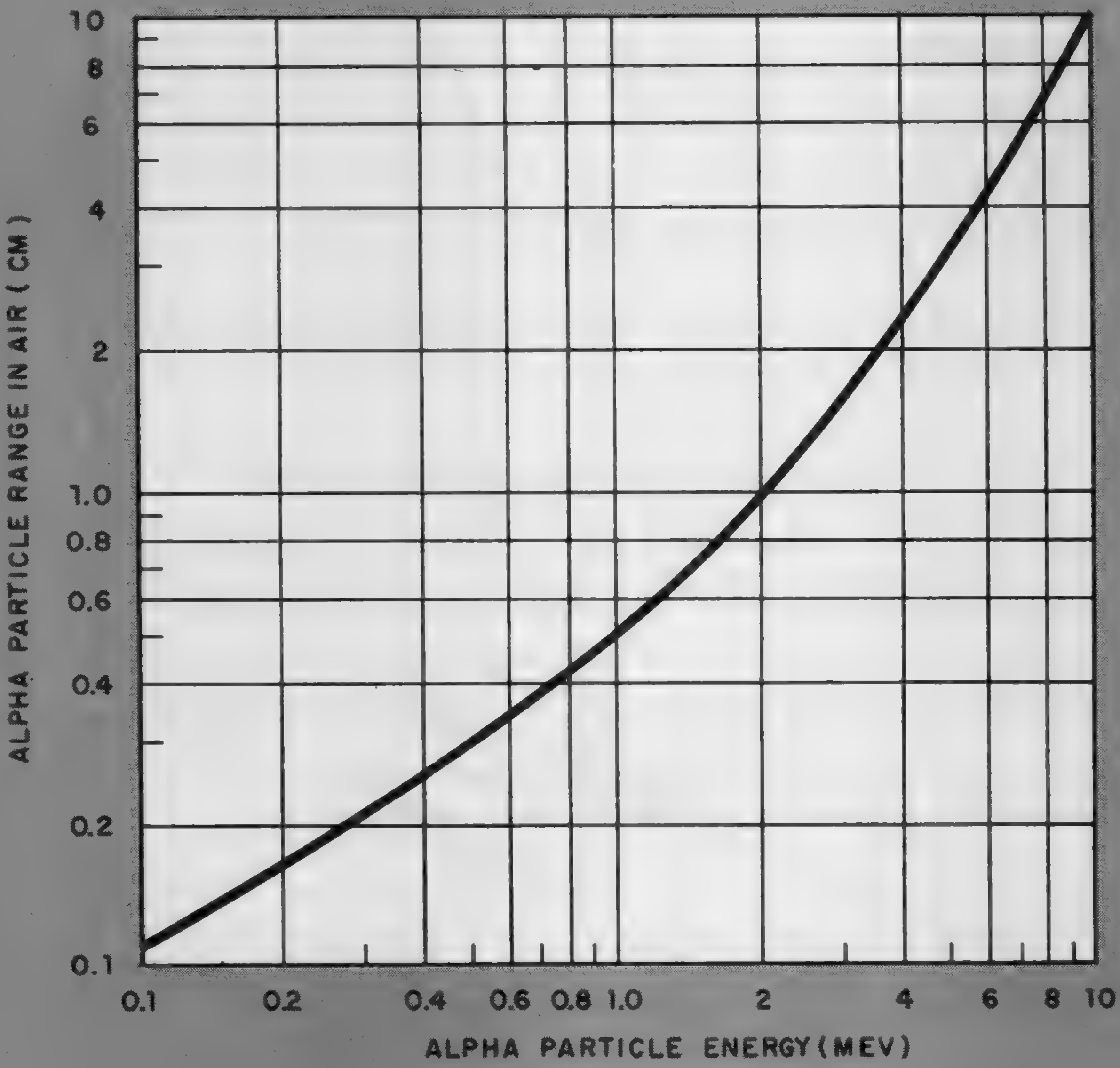


FIG. 2.6 MEAN RANGE OF ALPHA PARTICLES IN AIR

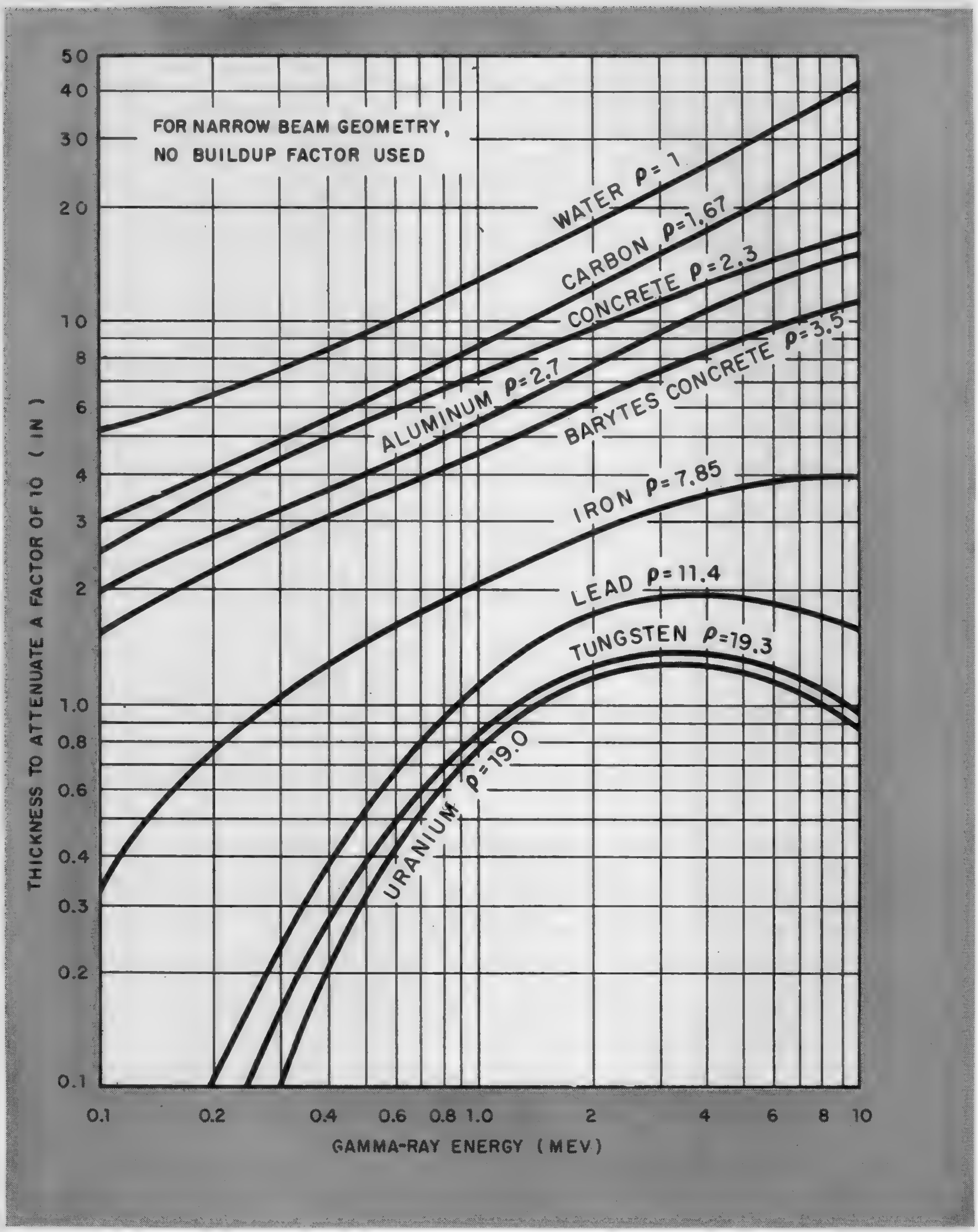


FIG. 2.8 TENTH-VALUE THICKNESS FOR GAMMA RAY ABSORPTION

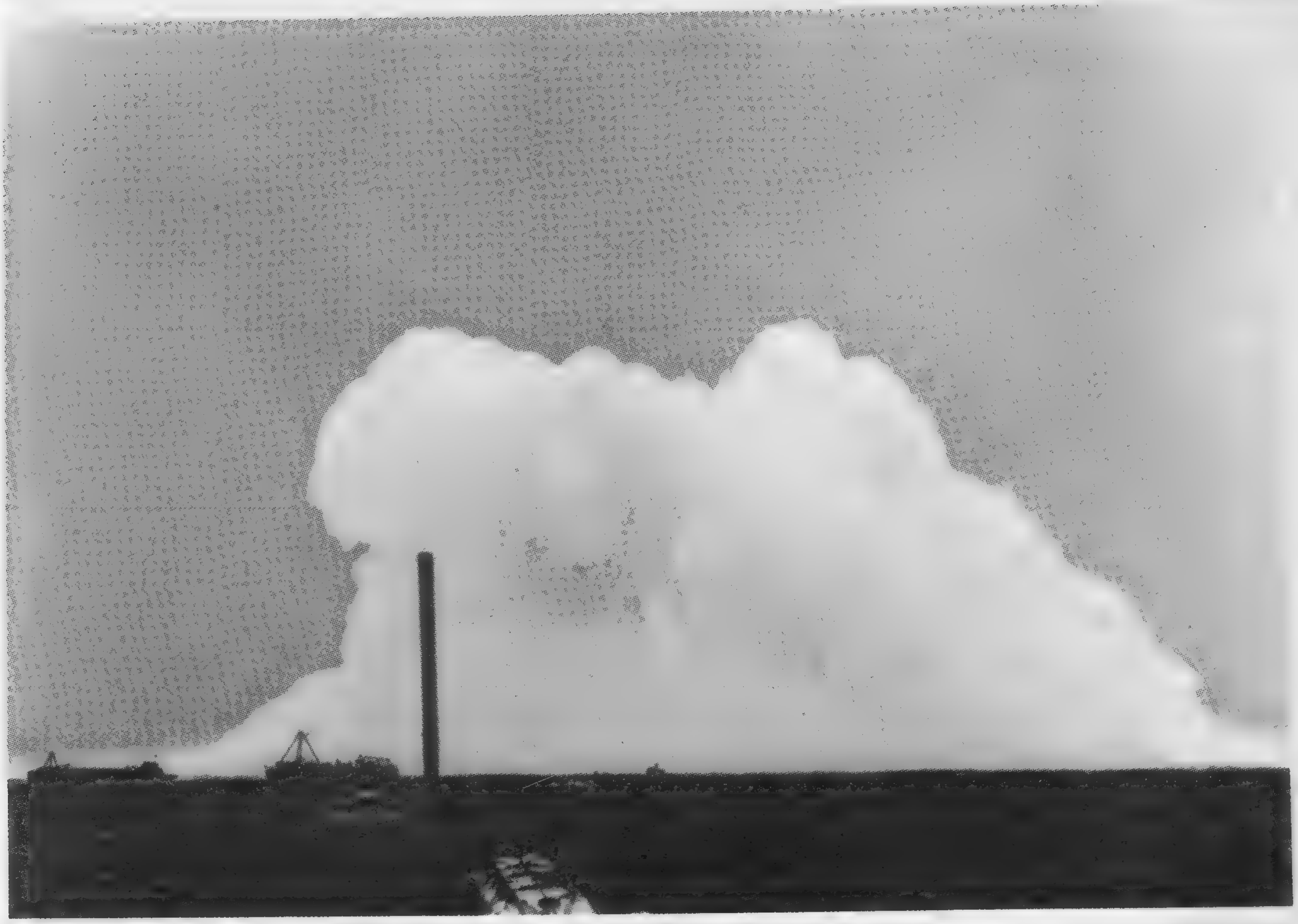
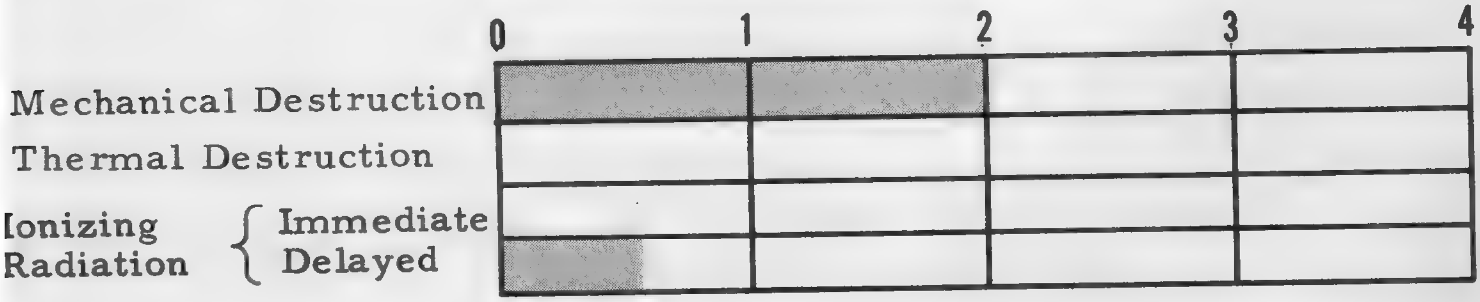


FIG. 2. 18 DEEP UNDERWATER BURST



In a deep underwater burst, Fig. 2. 18, the fireball forms a hot gas bubble consisting of the bomb detonation products, plus large quantities of steam. This bubble, in rising to the surface, pulsates, and, in so doing, loses some of its radioactivity in deep layers. To what extent it retains its ident ty as it approaches the surface is not known but, in these circumstances, there is no large cylindrical column of water and no well-defined visible "atomic cloud." A large fraction of the radioactivity is contained in the foam or froth in a circular region directly above the detonation point. There appears to be no extensive fallout, but the drifting mist may be dangerously radioactive within a few miles of SZ. Also the deposition of highly radioactive foam on a nearby shore would be hazardous.

Table 3. 1

Dose Rate from 1 Curie of Co^{60}, Cs^{137}, and Ra^{226}

Isotope	Half-Life	r/hr at 1 ft	r/hr at 1 meter
Co^{60}	5.2 yr	14.3	1.32
Cs^{137}	30 yr	3.83	.356
		Filter	
Ra^{226} in equilibrium with decay products	1620 yr	Thuringian Glass	0.93
		0.5 mm Pt-Ir	0.84
		1.0 mm Pt-Ir	0.78
		Each mm of lucite reduces the gamma output by 0.35%.	

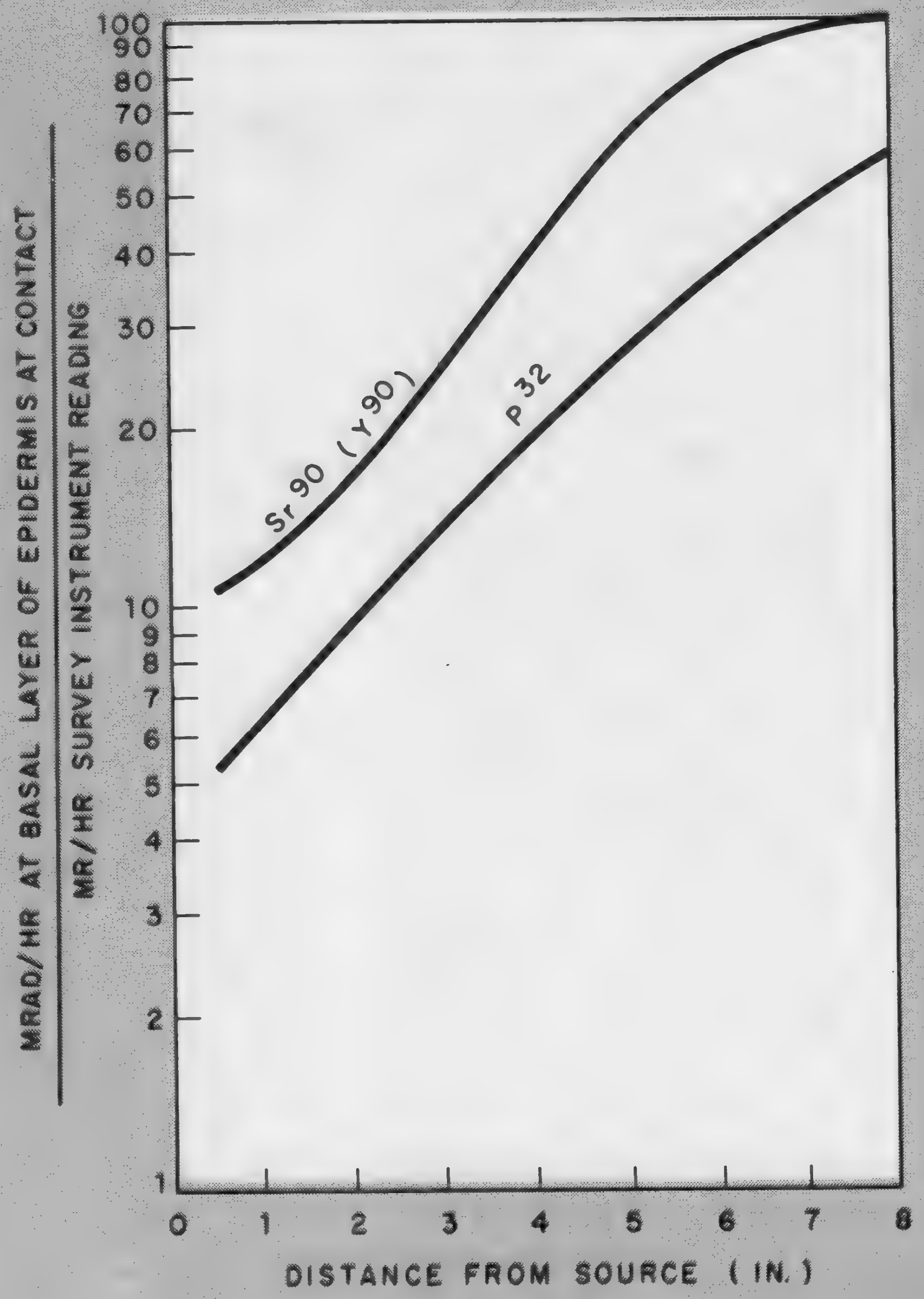


FIG. 3.16 RATIO OF CONTACT DOSE RATE AT THE BASAL LAYER OF THE EPIDERMIS TO SURVEY INSTRUMENT READING AS A FUNCTION OF SOURCE-TO-SURVEY-INSTRUMENT DISTANCE.

Type Instrument: CDV-700 G-M Type Radiac.

Table 3.2

Dose Rate vs Distance From 500 mg Ra Source

Calculated Dose Rate (mr/hr)	Distance (cm)	Measured Dose Rate (mr/hr)	Correction Factor
25,000	13.0	22,000	1.14
2,500	41.2	2,300	1.08
250	130	300	0.84
25	412	21	1.19
2.5	1304	3	0.84

(Meter Reading) x (Correction Factor) = Dose Rate

Gamma: The exposure dose rate from a gamma point source may be approximated to within 20% by the formula:

$D_1 = 6\ C\ E$, where

D_1 is the dose rate in r/hr at 1 foot from the source

C is the number of curies

E is the sum of all the gamma emissions of the isotope per disintegration in Mev.

Dose Rate in an Infinite Absorbing Source Material

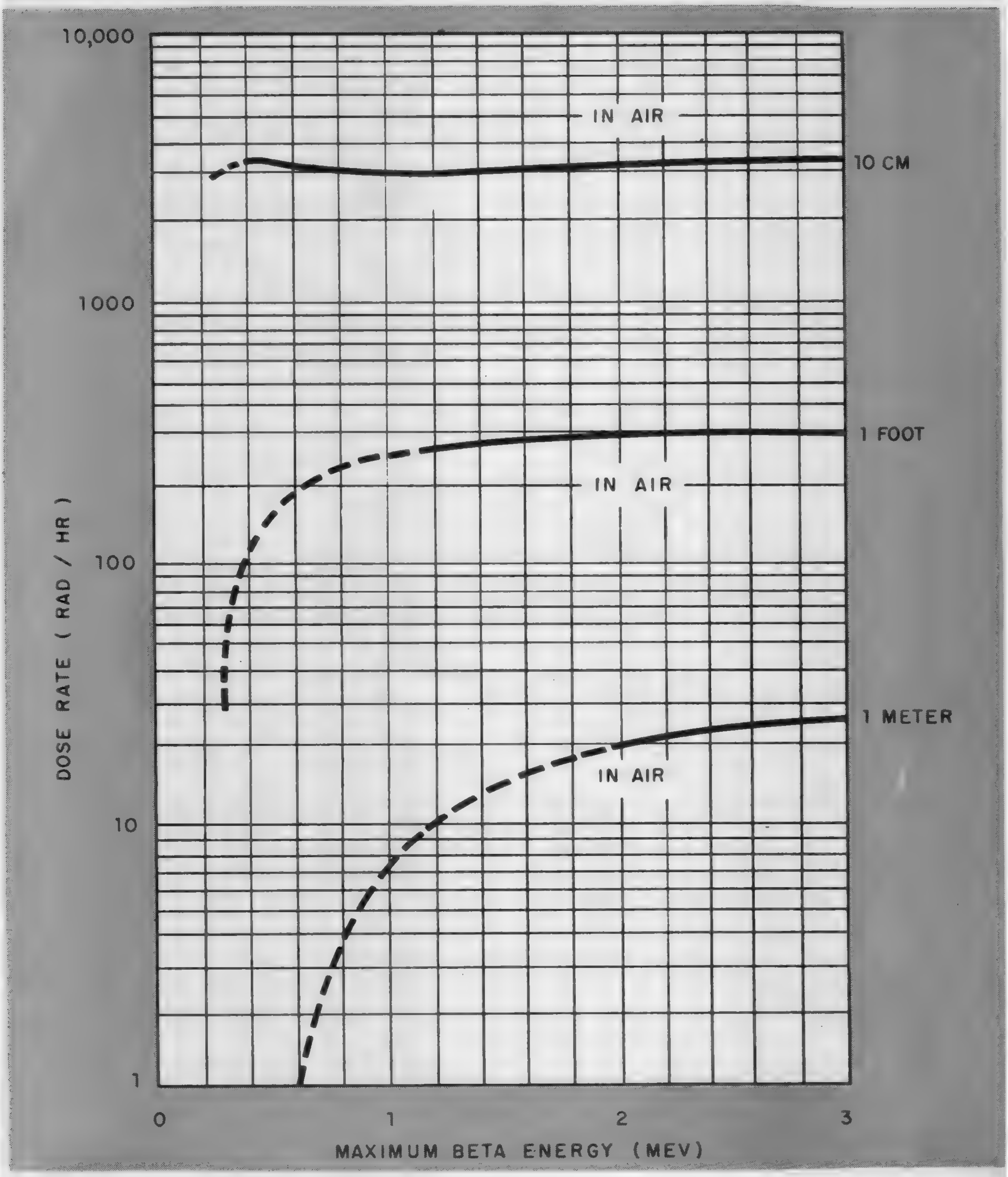
For a source uniformly distributed throughout an infinite absorbing medium, considerations of the conservation of energy lead to the relationship:

$D = 2.30\ C\ E$, where

C is the specific activity of the source in μc/gram,

D is dose rate in rads/hour,

E is the mean energy per disintegration in Mev.



(Note: Beta energy is maximum of spectrum; mean energy is assumed to be one-third of maximum.)

FIG. A-1 DOSE RATE FROM POINT BETA SOURCE OF STRENGTH 1 BETA CURIE

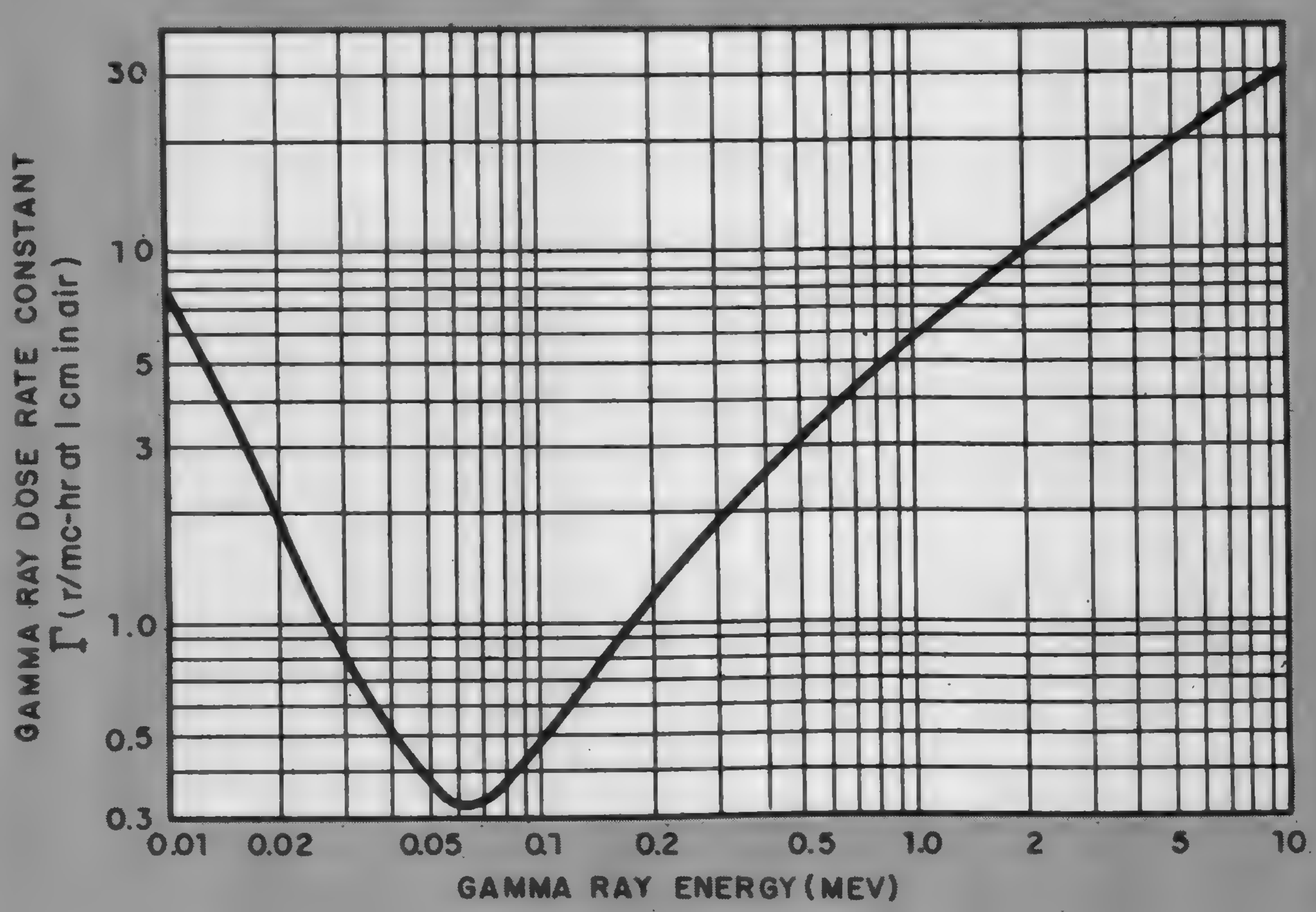


FIG. A-2 GAMMA RAY DOSE RATE CONSTANT, Γ (r/mc-hr at 1 cm), FOR A POINT SOURCE IN AIR AS A FUNCTION OF GAMMA ENERGY IN MEV

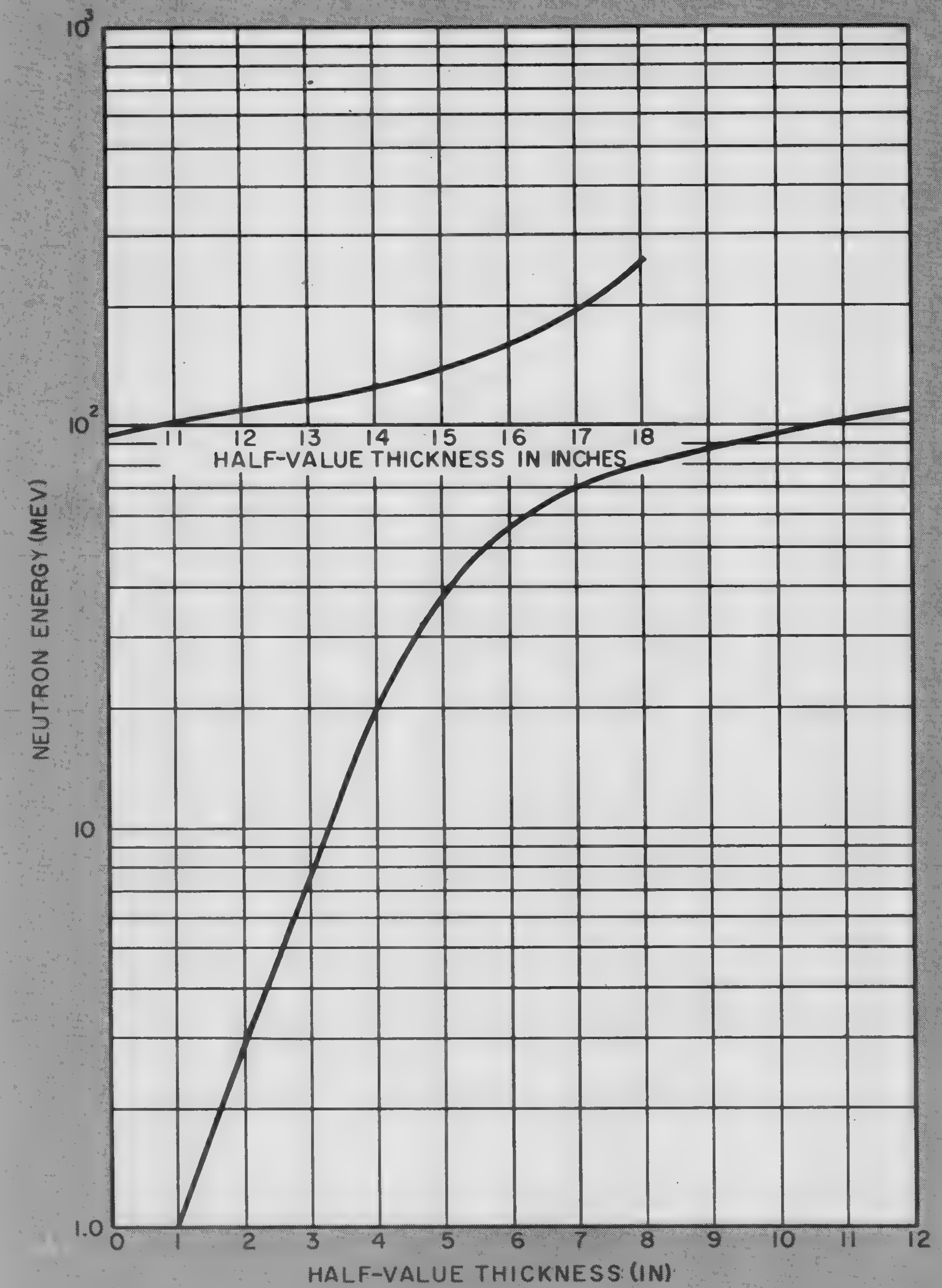


FIG. A-9 HALF-VALUE THICKNESS OF ORDINARY CONCRETE FOR FAST NEUTRONS

TABLE A-I

CALCULATED GAMMA RADIATION LEVELS FOR ONE CURIE OF SOME RADIOISOTOPES[1]

Isotope	Annihilation Radiation	QUANTUM ENERGY (E) IN MEV	Dose Rate at 1 Yard (r/hr)	Dose Rate at 1 Meter (r/hr)
		Nuclear gamma radiation (number in parentheses indicates photons/dis)		
Na^{22}	0.51 (2)	1.28 (1)	1.51	1.26
Na^{24}		1.38 (1) 2.76 (1)	2.31	1.93
Mn^{52}	0.51 (0.7)	0.73 (1) 0.94 (1) 1.46 (1)	2.30	1.92
Mn^{54}		0.84 (1)	0.54	0.45*
Fe^{59}		0.2 (0.03) 1.1 (0.57) 1.3 (0.43)	0.77	0.65
Co^{58}	0.51 (0.3)	0.81 (1)	0.67	0.56*
Co^{60}		1.17 (1) 1.33 (1)	1.59	1.32
Cu^{64}	0.51 (0.38)		0.137	0.114
Zn^{65}	0.51 (0.04)	1.12 (0.47)	0.36	0.30*
I^{130}		0.417 (0.4) 0.537 (1) 0.667 (1) 0.744 (1)	1.48	1.23
I^{131}		0.080 (0.063) 0.284 (0.063) 0.364 (0.809) 0.637 (0.093) 0.722 (0.028)	0.276	0.231
Cs^{137}		0.661 (0.92)	0.426	0.356
Ir^{192}		20 known lines 0.136 to 1.157 Mev	0.61	0.51
Au^{198}		0.411 (1) 0.68 (0.013) 1.09 (0.0025)	0.297	0.248
Ra^{226} & equilibrium decay products		Many known lines	1.005**	0.84**

* Isotopes have X-ray emission following electron capture whose contribution to I is negligible at 1 meter but would not be at distances of the order of 1 cm. Self absorption is ignored.

** With 0.5 mm Pt filter. This figure is the average of better measurements.

1 Excerpt from Radiological Health Handbook PB 121784, U. S. Dept. of Public Health, Education and Welfare, January 1957.

INTRODUCTION TO LONG-TERM BIOLOGICAL EFFECTS OF NUCLEAR WAR

CONTRACT NO. N228-(62479)69928
OCD WORK UNIT NO. 3119A

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

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April 1966

INTRODUCTION TO LONG-TERM BIOLOGICAL EFFECTS OF NUCLEAR WAR

By: CARL F. MILLER AND PHILIP D. LaRIVIERE

SRI Project No. MU-5779

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WASHINGTON, D.C. 20310

Through:

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Because of the differences in volatility among the various fission-product elements, fractional condensation would be expected to occur throughout the fallout formation process. The significant radiological property associated with the amount of a radioelement that condenses during the second period of formation is that the fraction condensed is considered to be potentially soluble and biologically available for assimilation by plants and animals. The more volatile radioelements in fallout, in fact, have been found to be most soluble and more biologically available than are the refractory elements. However, the fractional degree to which each element condenses in either period of condensation is expected to depend very much upon the temperature at which diffusion into the particle becomes limiting and the condensing radioelement is concentrated in the surface layer of the particle.

If all the materials that were produced in a land-surface nuclear detonation and all that entered the fireball volume remained together for the first 5 or 10 minutes after detonation, the radioactive compositions and the subsequent radioactive decay (and nuclide solubility) would be about the same for all fallout particles. However, it is known that all the entering particles do not remain together in the fireball and cloud for such periods of time. Immediately after the fireball expands to maximum size, it begins to rise in the air. The upward motion of the hot gases sets in motion a large-scale toroidal circulation because of the drag forces of the surrounding air. This toroidal motion, with circulation velocities in excess of 100 miles per hour, is probably responsible for pulling blast-loosened soil from the crater and crater lip into the rising fireball.

The circulation of the particles in the toroid should result in an earlier separation of the larger particles from the circulating volume(s) of condensing gases and should, by centrifugal forces, move them to the periphery of the toroid. When the circulating particles reach the periphery (or the bottom) of the cloud and the pull of gravity begins to exceed the upward drag forces of the air near the base of the rising cloud, the particles begin falling to earth. Other particles of the same size, not yet near the periphery of the toroid, may continue to circulate for a much longer time before they leave the base of the cloud. These views of particle circulation and formation are supported by (1) the relatively long period over which particles of a given size arrive on the ground, (2) the relatively early arrival times for close-in fallout, (3) the variation in composition of the radioelements on particles of different sizes, and (4) the variation in specific activity and radioelement composition among particles of a given size.

The concentration of the volatile radioelements in the radioactive compositions carried by the larger particles is generally found to be low. This lower relative concentration could occur only through the earlier ejection of the large particles from the volume of the fireball containing the radioelements (vapors plus small vapor-condensed particles). In addition, the large fallout particles from many low tower detonations do not contain or carry any soluble radioelements, and, therefore, these

particles must have been ejected when their surfaces were still at a very high temperature. Thus the toroidal motion is considered to be partially responsible for the observed differences in the gross radioactive decay and biological availability of different radioelements carried by fallout particles with different diameters.

The toroidal motion which apparently causes early ejection (early with respect to fall from the stabilized cloud) of the larger particles also can cause prolonged apparent buoyancy of the smaller particles. The latter would circulate for longer times and, after cooling, would remain in the volume to collect the more volatile elements on their surfaces. Except for the fallout particles with diameters less than about 50 to 80 microns, all appear to leave the cloud volume under influence of circulation.

Observed data on the properties of fallout from detonations on soils similar to those of likely targets in a nuclear war are nonexistent. In fact, only a few detonations in both the Eniwetok Proving Ground and Nevada Test Site have provided useful data for the development of fallout models for land-surface detonations. The large yield devices were all detonated over water, on coral atolls, or in the air. No evidence exists today for proving that all types of information on fallout obtained from these few weapons tests are satisfactory for use in developing reliable models that are designed to give quantitative estimates of the properties of fallout (and its distribution) from assumed detonations of high yield weapons on targets in the continental United States. Perhaps continued theoretical developments and concurrent supporting high temperature experimental work are the only remaining methods for improving and evaluating the validity of some of the input data for currently available fallout models.

The radionuclides in worldwide fallout are generally found to be quite soluble, and all the radionuclides are, to a large degree, biologically available. However, a fairly large number of fused-type particles are formed from the warhead or bomb materials as identified in stratospheric collections of bomb debris.[3] A large fraction of the worldwide fallout from a large-yield nuclear air explosion appears to be formed in the stratosphere at some time after the detonation through processes of coagulation and coprecipitation of the radioactive atoms with the natural stratospheric aerosol particles. The latter, composed mainly of water-soluble ammonium sulfate compounds, then serve as carrier particles for returning the radioactive debris to earth.

In all types of detonation conditions, the form and properties of the produced fallout are determined during the cooling period of the fireball and cloud, as well as at later times for the decay products of gaseous radioelements and for many other radioelements in airbursts that produce the worldwide fallout. The materials that enter, or are in, the fireball at these times are important factors in determining the properties of the fallout particles. These formation processes set the stage for all subsequent radiological interactions between the fallout materials

and the biological and ecological environment in which the materials are deposited.

One of the chief difficulties in the prediction or computation of levels of fallout at a given location, in addition to the problems of defining the fallout particle cloud source discussed above, is the analysis and prediction of the wind structure as the major influence in distributing the fallout particles over the earth's surface. Other major factors for which very little accurate data exist, especially for fallout from large yield detonations over silicate soils, include (1) the variation of the specific activity with particle size and (2) the influence of the environmental material (soils and other likely target materials) on the gross particle-size distribution of the fallout (i.e., by particle number, mass, or radioactivity content).

A comparison of several currently used fallout models (or fallout pattern scaling systems) is shown by the relative areas within stated fallout radiation rate contours in Table 1. The differences in the areas enclosed by stated standard intensity contours among the various computing systems for the two weapon yields and wind conditions are generally not small. Assumptions regarding the fraction of the gross fallout activity on particles of a given diameter and the locations of the particles in the initial cloud source are likely major causes of the differences among the models.[2] The integrated activity in the fallout patterns within the 1 r/hr at 1 hr contour, for the two cases of Table 1, gives the following values for the radiation rate conversion factor (in r/hr at 1 hr per KT/sq mi):

Case A: WSEG-RM10 - 1,500
ENW - 1,460
Anderson - 1,550
SFSS - 1,430

Case B: WSEG-RM10 - 2,500
AFCIN - 800
WB - 2,000 (approximately)
WSEG-NAS - 2,400

For Case B, the theoretical value of the conversion factor for unfractionated fission products is 3,600.[2] The parameters and data relating to the evaluation of the conversion factor from measured quantities on the fallout from Shot Small Boy in Operation SUN BEAM are discussed in Reference 8.

Four additional types of radiological hazards to biological species, in addition to the more general external hazards from gamma radiation, are known. These are (1) the contact hazard, (2) the inhalation hazard, (3) the beta-field hazard, and (4) the internal hazard from ingested radionuclides.

Table 1

RATIO OF AREAS WITHIN STATED STANDARD INTENSITY CONTOURS
FOR FALLOUT PATTERNS COMPUTED FROM VARIOUS MODELS
RELATIVE TO THOSE FROM THE WSEG-RM10 MODEL[a,b]

Model Designation	Standard Intensity (r/hr at 1 hr) 1	10	100	1,000
	Case A. 10-MT yield, 15 mph wind speed (100 percent fission)			
ENW (1957)[5]	8.66	1.86	0.70	0.62
Anderson[6]	1.40	1.14	1.00	0.96
Simple Fallout Scaling System[2]	0.67	0.71	0.83	1.10
	Case B. 1-MT yield, 25 mph wind speed, 0.2 knots/10^3-ft vertical shear (100 percent fission)			
AFCIN[7]	0.15	0.18	0.26	0.57
WB (1962 ENW)[7]	2.16	1.18	0.67	0.40
WSEG-NAS[7]	1.96	1.36	0.87	0.60

a Standard intensities calculated from WSEG-RM10 Model were first multiplied by 0.56 to account for terrain shielding and instrument response for the 10-MT-yield weapon fallout pattern

b From Reference 4

Table 3

FRACTION OF SR-90 IN THE RUNOFF WATER FROM CROP LAND[a]

Crop	Fraction of Deposited Sr-90 in the Runoff Water	Fraction in the Runoff Water per Inch of Rainfall	Runoff Water (inches)
	LaCrosse, Wisconsin; 16 percent slope; March-August 1957; Fayette silt loam		
Corn	0.045	0.0020	0.93
Oat	0.041	0.0018	1.25
Clover[b]	0.0035	0.00016	0.15
	Tifton, Georgia; 3 percent slope; March-December 1957; Tifton loamy sand		
Corn	0.014	0.00034	1.32
Oat[b]	0.0044	0.00011	0.37
Peanut	0.014	0.00035	1.20

a From Reference 21

b Ground cover established before the measurements were started

RESPONSE OF ANIMALS TO BRIEF EXPOSURES IN EXTERNAL GAMMA RADIATION FIELDS IN TERMS OF THE LD_{50} IN 30 DAYS[a]

Species	$LD_{50}/30$ (roentgens)
Dog	280
Guinea pig	340
Goat	350
Mouse	440
Swine	510
Sheep	520
Cattle	540
Rat	640
Burro	650
Monkey	760
Rabbit	800
Poultry	900

a From References 11, 28, 29, and 30: the listed $LD_{50}/30$ values were used in the calculations described in this report. Other $LD_{50}/30$ values, differing from those listed by as much as a factor of 2, are reported in References 93, 94, and 95. Some of these are: dog, 319; sheep, 360; burro, 375; swine, 390; rat, 936; and mouse, 940. The basic causes of these differences remain to be clarified.

Table 7

LD_{50}/30-DAY DOSES FOR BRIEF EXPOSURES OF FISH AND SHELL ANIMALS[a]

Species	LD_{50}/30 Days (rads)
Adult fish	1,000- 2,000
Crustacean	800-100,000
Mollusc	4,000-500,000

a From Reference 11

Some of the easily observable biological responses of plant parts (all parts exhibit response) are: (1) roots--reduction of growth and inhibition of new root formation; (2) stems--dwarfing, excessive branching, local swelling, fasciation, formation of adventitious roots, and tumor growth; (3) leaves--reduced blade development, dwarfing (asymmetrical blades), abnormal veination, decrease in chlorophyll (discoloration), and change in texture (older leaves become dry, brittle, and coarse and young leaves thicken and become leathery); and (4) buds and flowers--retarded formation, reversion to vegetative growth, fasciation, and changes in color and form.

Notable changes in plant growth habits after exposure to critical doses of radiation include the early dropping of leaves (deciduous trees) and the retardation of bud and new-shoot formation. The reduction in reproductive capability after exposure is related to the effect on vegetative growth (plant vigor), the retardation of flowering, and the direct damage to the parts of the cells that participate in the reproductive cycles of the plant.[32] The extreme combination of all the various radiation damage manifestations results in death of the plant.

The relative radiosensitivity of plants ranges over a factor of at least 5,000 from algae and bacteria, which are the most resistant or least affected by radiation, to the gymnosperms, which are among the most radiosensitive of the plants. Among the higher plants, the range in chronic, or protracted, doses to produce a similar biological response is the order of a factor of 500.

The reduction of vegetative growth of plants after exposure to nuclear radiation is apparently caused mainly by a reduced rate of cell division; since reduced growth is usually the first gross observed effect of the exposure, it is believed that the apical meristem regions are highly radiosensitive.[32] The radiosensitivity of young growing plants is probably highest.[33] Growth retardation appears to have a threshold dose; much of the plant growth retardation data can be represented by a function of the form

$$G = G_o \exp \left[-k_D (D - D_o) \right] \tag{1}$$

where G is the growth characteristic for an exposure dose of D roentgens, G_o is the characteristic for the controls (zero dose), D_o is the threshold dose, and k_D is a growth retardation coefficient. Some values of k_D and D_o for different plant species, as derived from reported data, are shown in Table 8.

Basic relationships between plant cell nucleus characteristics and radiosensitivity recently have been derived by Sparrow and Woodwell[32] from correlations between these characteristics and data on the response of plants to external gamma radiation. The cell nucleus variables include (1) cell nucleus or chromosome volume, (2) cell nucleus DNA content,

Table 8

ESTIMATED PLANT RETARDATION THRESHOLDS
AND GROWTH RETARDATION COEFFICIENTS
FOR SOME PLANTS EXPOSED TO GAMMA (AND X) RADIATION[a]

Species	Response	k_D (roentgens^{-1})	D_o (roentgens)	Time of Total Exposure
Pinus strobus (seedlings)	Leader length growth	4.6×10^{-4}	910	15 months
Taxus med. cv. hatfieldii	Number of growth buds	1.3×10^{-3}	850	12 months
Quercus alba	Number of leaves	2.3×10^{-4}	5,500[b]	6 months
Pinus regida	Terminal growth	-	360	6 months
Quercus alba	Terminal growth	-	1,800	6 months
Wheat (seedlings)	Growth[c]	-	250[c]	acute dose

a From References 32, 33, 34, and 35

b Cs-137 source; unmarked numbers are for Co-60 source

c Maximum growth retardation occurred for exposures at 2 days after germination; X-radiation

Table 9

PLANT RESPONSE RELATIVE TO MORTALITY (LD_{100}) OF HERBACEOUS ANNUALS FOR CO-60 GAMMA RADIATION[a]
(Exposure Times from 8 to 12 Weeks)

Response	Fraction of LD_{100} Dose Rate
Normal appearance	0.11
10 percent growth reduction	0.26 ± 0.02
Failure to set seed	0.31 ± 0.06
50 percent growth reduction	0.34 ± 0.04
Pollen sterility (100 percent)	0.41 ± 0.04
Floral inhibition or abortion	0.44 ± 0.04
Growth inhibition (severe)	0.58 ± 0.03
LD_{50}	0.75 ± 0.02
LD_{100}	1.00

a From Reference 32

Table 10

SINGLE ORAL INGESTION LEVEL OF SEVERAL RADIONUCLIDES BY ADULT SHEEP CAUSING SERIOUS INJURY OR DEATH[a]

Radionuclide	Ingestion Level (atoms ingested/kg body weight)	
	Serious Injury[b]	Lethal ($LD_{50}/30$)
Sr-90	4.7×10^{16}	4.7×10^{17}
I-131	7.4×10^{12}	5.6×10^{14}
Cs-137	2.5×10^{16}	2.5×10^{17}

a From Reference 11

b Type of injury not specified

Table 11

ESTIMATED RADIATION EXPOSURES FOR LIKELY RECOVERY OF TYPICAL ECOSYSTEMS[a]

Major Ecosystem	Exposure Dose for No Significant Effect (roentgens)	Exposure Dose for Likely Recovery (roentgens)	Exposure Dose for Likely Recovery in about 2 Years (roentgens)
Typical farmland	200	200	-
Coniferous forest	200	200 — 2,000	2,000
Deciduous forest	200	200 — 10,000	10,000
Grassland	2,000	2,000 — 20,000	20,000
Herbaceous successional	4,000	4,000 — 70,000	70,000

a From Reference 43

External Contamination of Plants

The external contamination of plants by local fallout particles is discussed in detail in References 9 and 10. The major portion of the currently available data on the subject was obtained in the Costa Rican experiments; however, in this described study, which was initiated prior to the Costa Rican work, the plant contamination factors that were used were those derived from the field test data, as shown in Figure 3. In the model, the average effect of weathering on the foliar deposits was assumed to be represented by

$$a_L = a_L^o e^{-0.05(t-\bar{t}_a)} \tag{7}$$

where a_L is the contamination factor in terms of the ratio of the activity or weight concentration of the fallout on the foliage to the surface density of the fallout, and $\bar{t}_a$ is the average time of arrival of fallout. The factor, 0.05, corresponds to a weathering half-life of 14 days, as discussed in References 9 and 50. Newer data on the effect of wind and rain on foliar contamination indicate that weathering effects, in general, do not correspond to that given by Equation 7; however, the computations of this study were made using Equation 7 and therefore underestimate, to some degree, the contamination levels on most food crops due to the contamination of the foliage by local fallout. The initial values of the contamination factors, $a_L^L (\approx a_L^o)$, used in the calculations are summarized in Table 12.

Entry of radioactivity from worldwide fallout into plants is made via two major routes: (1) direct foliar absorption of radionuclides in solution in rain and (2) root uptake from the accumulated nuclides in the soil. Measurements of the total specific activity of the edible parts of plants therefore represent the sum of both modes of entry, and the problem becomes one of separating the total into parts. There are many data available on root uptake from pot experiments so that it would appear that a reliable approach would be to subtract that amount of activity due to root uptake from the soil. The usual result, however, is that all or more of the observed activity is accounted for by root uptake alone. It would therefore appear that the uptake of crops grown in the field is different from that of crops grown in pot experiments.

Among the reasons for such differences, aside from the usual uncertainty in the number of atoms (such as Sr-90) per unit area of soil, are the effects of distribution in depth in relation to root habit and the long-term availability of the nuclide in question. The method usually followed in assessing foliar and root uptake from worldwide fallout is to set up an equation with two unknowns and solve these over successive years.[51,52] This method, for any nuclide, is represented by

Figure 3

EXPERIMENTAL VALUES OF a_L

AS A FUNCTION OF a_o FOR A 15 MPH WIND SPEED

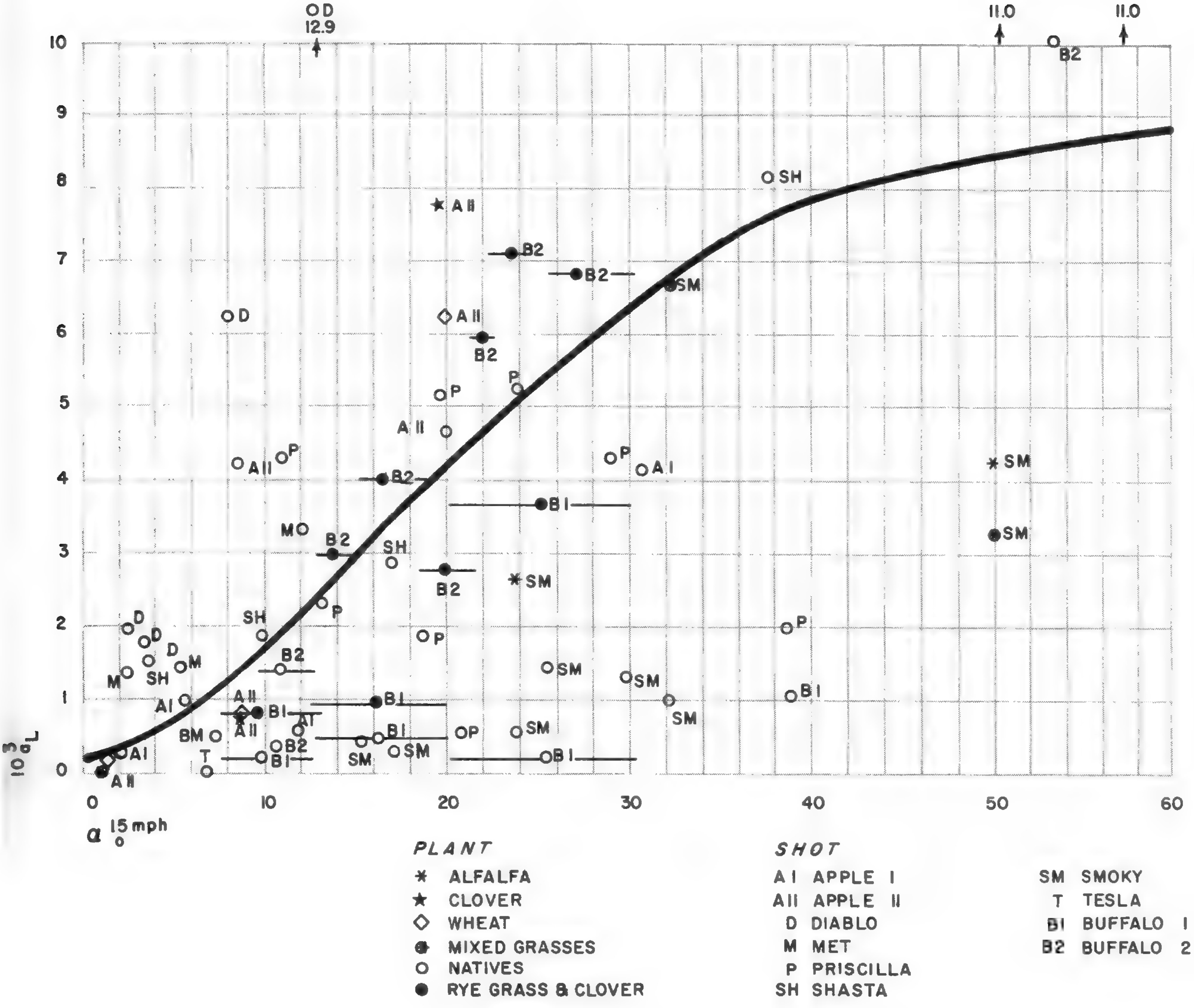

Table 12

FOLIAR CONTAMINATION FACTOR VERSUS α_o^{15}
AND RELATED PARAMETERS

α_o^{15}	Particle Falling Velocity v_f^o (mph)	Particle Diameter d (microns)	Foliar Contamination Factor a_L^L (sq ft/gm)
0.15	100	8,000	0.000200
0.50	30.0	1,170	0.000225
1	15.0	500	0.000250
5	3.00	120	0.000750
6	2.50		0.000930
10	1.50	75	0.00170
15	1.00		0.00300
20	0.75	50	0.00425
25	0.60		0.00535
30	0.50	40	0.00635
35	0.4286		0.00720
45	0.3333		0.00815
75	0.2000	25	0.00912
100	0.1500		0.00945
150	0.1000		0.00975
300	0.0500	13	0.00997
400	0.0375		0.0100
↓	↓		↓
∞	0	0	0.0100

Source: Derived by Stanford Research Institute

Table 13

ESTIMATED VALUES OF a_L^w FOR SELECTED CROPS AND RADIONUCLIDES

Crop	a_L^w $\left(10^{-5}\ \frac{\text{atoms/gm dry weight}}{\text{atoms/sq ft soil}}\right)$ Sr-89, Sr-90	Zr-95, Ce-144	Ru-106	Cs-137
Corn	90	0.1	0.3	40
Sorghum	90	9.0	27	450
Wheat	90	9.0	27	425
Oat	90	9.0	27	450
Barley	30	3.0	9.0	180
Dry bean	20	2.0	6.0	800
Soy bean	20	2.0	6.0	240
Alfalfa	600	600	600	600
Clover	700	700	700	700
Potato	1	0.1	0.3	100
Green pea	6	0.6	1.8	18
Sugar beet	1	0.1	0.3	100
Tomato	500	500	500	1,750
Snap bean	20	2.0	6.0	60
Cabbage	300	300	300	1,050
Dry Onion	1	0.1	0.3	100
Carrot	1	0.1	0.3	100
Lettuce	500	500	500	1,750
Apple	50	5.0	15	150
Peach	300	30	90	900
Orange	50	5.0	15	150

Source: Stanford Research Institute

Exposure of both parents to 700 roentgens would increase the stillbirths and early childhood deaths from the present 5 percent to 7 percent in the first generation. If the entire population was exposed to 700 roentgens, one additional stillbirth or early childhood death per conception by the originally exposed parents could be expected over many generations.

Infant mortality in the first year of life would increase from 26,000 to 29,000 per million parents in the first generation if both parents are exposed to 700 roentgens. If the entire population is exposed to 700 roentgens, infant deaths could be expected to increase by 91,000 per million originally exposed parents over many succeeding generations.

If both parents are exposed to 700 roentgens, major defects in newborn infants could be expected to increase from the present 2.5 percent to about 3.2 percent. If the entire population were exposed to 700 roentgens, 210,000 additional birth defects could be expected per million live births in the first generation. Unfortunately, no data are available for estimating the genetic effects that might result from mixed doses (e.g., one parent being exposed to 700 roentgens and the other having no exposure).

Gut Response, Internal Emitters

Absorbed Dose (rads)	Response
100	Threshold for nausea, vomiting
1,000	Threshold for tumor production
1,300	Threshold for acute radiation injury

In the cases considered in the third section of this report, the absorbed dose to the lower large intestine was well below the threshold for nausea and vomiting.

Thyroid Response, Internal Emitters[a]

Absorbed Dose (rads)	Response
10,000 ± 6,000	Threshold for hypothyroidism
80,000 ± 20,000	Central destruction of thyroid
150,000 ± 50,000	Complete destruction of thyroid

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a For adult humans. Infant thyroids are more highly susceptible to damage; threshold exposure dose for carcinoma in the thyroid of children and young adults for a brief exposure is about 200 roentgens.

Table 28

FRACTION OF GROSS FOLIAR CONTAMINATION
FROM LOCAL FALLOUT ASSOCIATED WITH EDIBLE PLANT PARTS

Crop	f_p[a]
Sweet corn	0.005
Sorghum grain	0.005
Wheat	
Grain	0.005
Flour	0.001
Oat	
Hay	0.5
Grain	0.005
Barley	0.005
Dry bean	0.005
Soybean	0.005
Alfalfa	0.5
Clover, timothy, and other hay	0.5
Potato	0.01
Green pea	0.005
Sugar beet	0.01
Tomato	0.01
Snap bean	0.005
Cabbage	0.05
Dry onion	0.01
Carrot	0.01
Lettuce	0.05
Apple	0.01
Peach	0.06
Orange	0.01

a All nuclides

Table 31

GAMMA RADIATION SENSITIVITY OF PLANTS

Common Name	7-Day Lethal Dose (roentgens)
Grains	
Corn	7,500
Sorghum	(7,500)[a]
Wheat	10,000
Oat	25,000
Barley	(20,000)
Field Crops	
Dry field and seed beans	12,000
Soybean	12,000
Alfalfa	50,000
Clover and timothy	25,000
Irish potatoes	4,500
Tobacco	50,000
Green pea	10,000
Sugar beet	(12,000)
Tomato	3,000
Sweet corn	7,500
Snap bean	(5,000)
Cabbage	50,000
Dry onion	5,000
Carrot	(5,000)
Lettuce	12,000
Pasture	7,500
Trees	
Apple	(5,000)
Peach	(5,000)
Orange	(5,000)
Loblolly pine	7,500
White pine	7,500
Hickory	< 30,000
White oak	> 50,000
Black oak	> 50,000

a Values in parentheses are estimated values (also indicate plant species for which no response data have been reported); the estimates were made using the assumption that similar species have similar responses to a given radiation dose.

Table 34

BODY AND ORGAN DOSES IN REMS TO ADULT HUMANS FOR INGESTION OF 1 LITER OF WATER PER DAY FROM THE 1ST AND 7TH DAY TO THE 30TH AND 91ST DAY AFTER THE HM ATTACK FOR FIVE REPRESENTATIVE CITIES[a]

City	t_o[b] / t	Total Body		Bone[c]		Thyroid		Lower Large Intestine	
		1	7	1	7	1	7	1	7
St. Louis	30	5.41	2.95	21.8	16.1	6,950	3,440	88.1	60.5
	91	10.85	7.57	80.6	65.6	9,550	5,670	144	116
Philadelphia	30	0.348	0.190	1.41	0.971	445	220	5.71	3.9
	91	0.701	0.490	5.11	4.11	611	364	9.34	7.56
Baltimore	30	0.0373	0.0205	0.155	0.108	47.3	23.4	0.612	0.420
	91	0.0767	0.0539	0.574	0.463	64.9	38.6	1.009	0.815
Boston	30	0.00553	0.00869	0.0228	0.0157	7.03	3.47	0.0911	0.0641
	91	0.01129	0.00792	0.0856	0.0691	9.64	5.74	0.151	0.122
Tulsa	30	0.000509	0.00028	0.00214	0.00149	0.642	0.418	0.0084	0.00575
	91	0.00109	0.000743	0.00816	0.00659	0.881	0.525	0.014	0.0113

a Dose conversion factors taken from Reference 38
b Time in days
c Dose to total bone; does not include contributions from La-140 (daughter of Ba-140)

Figure 6

FORES SURVIVAL FROM THE HM ATTACK

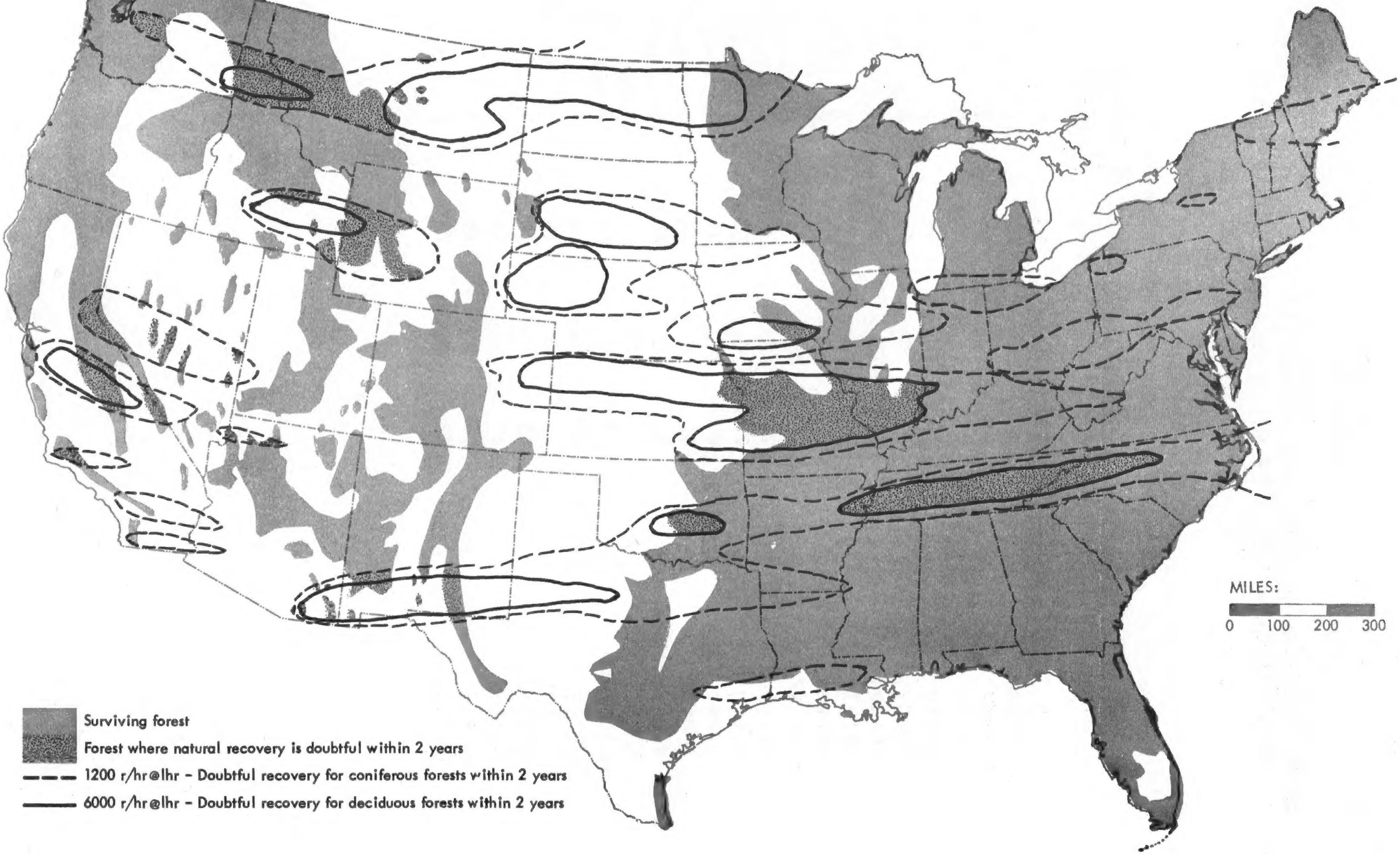

Table 50

POSTATTACK PRODUCTION POTENTIAL PER CAPITA
(Values in Percent of Normal)

Crop	HM Attack		MC Attack	
	Existing Shelter	Good Shelter	Existing Shelter	Good Shelter
Corn	92	92	92	97
Sorghum	140	95	93	100
Wheat	88	84	80	92
Oat	102	99	92	99
Barley	88	88	72	95
Bean, dry field	112	102	112	101
Soybean	130	98	101	97
Alfalfa	99	101	94	100
Hay	98	100	93	100
Potato	99	76	86	82
Green pea	146	104	114	101
Sugar beet	106	87	90	92
Tomato	131	85	109	98
Sweet corn	127	102	108	100
Snap bean	159	101	114	101
Cabbage	164	104	114	101
Onion	144	97	108	98
Carrot	171	104	105	101
Lettuce	171	102	114	101
Apple	117	93	106	97
Peach	112	84	111	99
Orange	126	88	114	101
Bull, steer, and calf	85	51	83	74
Milk cow	94	56	93	83
Swine	78	47	85	76
Sheep	106	66	91	81
Chicken	101	60	94	84

TITLE: Introduction to Long-Term Biological Effects of Nuclear War

By: Carl F. Miller and Philip D. LaRiviere

SUMMARY:

This report summarizes the state of knowledge and concepts about the reaction of biological systems to effects of nuclear weapons under nuclear war conditions, about the likely extent of damage to agricultural and wildlife ecosystems under nuclear war conditions, and about the factors involved in the long-term recovery potential of these systems after damage. In the study, an attempt was made to organize the available information for objective discussion of the subject, to outline the state of the art regarding capabilities to use the information (as well as its availability), and to make estimates of radiological effects using the available data and available (or new) computational methods.

Within the reliability of the current information on the biological response of biological species to radiation exposures, the results of the study lead to the conclusion that long-term biological and ecological effects would not be so severe as to inhibit or seriously delay the national recovery after a nuclear attack similar to one of those assumed in the study. Rather, the major problems of population and biological resource survival are concluded as being associated with the short-term biological effects that would result from the exposure of all biological species to gamma radiation from fallout. The alleviation of these effects thus centers on the availability of shelter for the protection of the population and a local capability for organized efforts to recover food and water and other such resources that would be required to maintain the health of the survivors as a coherent work force in the early postattack period. This is the time period after attack when the need for knowledgeable leadership would be critical and when errors in recuperative actions would be the most likely to lead to secondary fatalities.

For several assumed types of nuclear attack, the effects of the radiation from fallout in some areas of the country could result in fatal doses to all higher forms of life in exposed conditions. A few percent of the total land area of the country would likely be denuded of vegetation for a short period of time. However, the location and extent of these areas, with respect to other aspects of resource damage and economic recovery problems, are such that the ecological consequences of the biological damage in these areas could have little or no influence on national recovery. Essentially all of the economically important agricultural land is recoverable within the first year after attack for the case in which the existing shelter system is used.

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